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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CIX.—No. 2830.] *LONDON: FRIDAY, MARCH 26, 1920.* [*Registered at the General Post Office as a Newspaper.*] PRICE... 1s. BY FOREIGN POST ... 1s. 5d.

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For Boilers of all types.
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See their Illus. Advertisement, page 131, last week.

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See Advertisement page 76. 8187

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See displayed advertisement every alternate week.
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SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS
WATER SOFTENING and FILTERING. 8726

Yarrow Patent Water-tube Boilers. 7769
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Matthew Paul & Co., Ltd.
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See Full Page Advt., page 98, March 5.

Forgings.
Walter Somers & Co., Ltd., HALESOWEN. 7116

Head, Wrightson & Co., LIMITED.
See Advertisement page 100. 3403

Taylor & Challen Presses. 8166
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement, March 5.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 7908

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BUILDERS of RAILWAY CARRIAGES & WAGONS.
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Machine and Engineering WORK of all description undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work, moderate charges.—ROSSER & RUSSELL, LTD., Queen's Wharf, Hammersmith.
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FLOATING CRANES. COAL BUNKERING VESSELS.
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See half-page Advert. last week and next week. 8490

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 7941
See half-page Advertisement page 22, March 19.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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Founded 1854 by SIR. WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 8443

The National Foremen's ASSOCIATION OF THE ENGINEERING AND ALLIED TRADES. (Registered under the Trade Union Act.)

An Association specially formed to look after the interests of Foremen on their Supervisory Capacity. C 508

All communications to— H. W. RHID, General Secretary. Head Offices— 91, High Holborn London, W.C.1.

PATENTS AND DESIGNS ACT, 1907.

Notice is Hereby Given that

James Howden & Company, Limited, and James Howden Hume, both of 195, Scotland Street, Glasgow, seek leave to amend the Specification for Letters Patent No. 135049, for "Improvements in or relating to Glands for Turbines." Particulars of the proposed amendment were set forth in the Illustrated Official Journal (Patents), issued on the 17th March, 1920. Any person, or persons, may give notice of Opposition to the Amendments by leaving Patents Form No. 15, at the Patent Office, 25, Southampton Buildings, London, W.C. 2, within one calendar month from the date of the said Journal.

W. TEMPLE FRANKS, Comptroller-General. F 485

STRASBOURG RIVER SHIPBUILDING COMPANY.

It is Announced that the SOCIETE DES CHANTIERS ET ATHLIERS DU RHIN FRANCAIS (Capital Frs. 10,000,000) will shortly be formed at Strasbourg.

After a complete examination, the SOCIETE DES CHANTIERS ET ATELIERS AUGUSTIN NORMAND, have decided to extend to this Company their scientific co-operation.
The new Company will be founded by the intermedium of the Soc. d'Etudes "LE CONSORTIUM," 6, Boulevard de la Madeleine, Paris, and all the principal Banks of Alsace-Lorraine, viz.: BANQUE DE MULHOUSE, BANQUE D'ALSACE LORRAINE, BANQUE STAEHLING VALENTIN, and SOCIETE GENERALE D'ALSACE LORRAINE. F 492

Inst. C.E. Exams.—Over 300 successes by Correspondence Coaching. Several prizes. Sec. "U" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7434, Offices of ENGINEERING.

Correspondence Courses for B.Sc., Inst. C.E., I. Mech. E., all ENGINEERING EXAMS. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to MR. THEVOR W. PHILLIPS, B.Sc. (Hons.), Assoc.M.Inst.C.E., M.R.S.I., etc., 9-10, Trafford Chambers, 58, South John Street, Liverpool. 8423

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Engineering Special Classes. Marine & Aero-Engines, Alternating Currents, Wireless Course, Ferro-Concrete, Refrigeration, Pract. Maths. and Calculus.—PENNINGTONS, University Tutors, 234, Oxford Rd., Manchester.

TENDERS.

Tenders Invited for Supply of TWO 50/60 HP. Petrol-paraffin Marine MOTORS suitable for motor yacht.

Specification from OGILVIE & PARTNERS, LTD., Consulting Engineers, 104, High Holborn, W.C. 1. F 548

The COMMISSIONERS OF HIS MAJESTY'S WORKS, etc., are prepared to receive

Tenders, before Eleven a.m. on Wednesday, 7th April, 1920, addressed to the SECRETARY, H.M. Office of Works, etc., Storey's Gate, Westminster, London, S.W. 1, for the supply of CONDUIT TUBES and FITTINGS during a period of 12 months from date of acceptance of Tender.

Forms of Tender, etc., may be obtained on application to the CONTROLLER OF SUPPLIES, H.M. Office of Works, etc., King Charles Street, Westminster, London, S.W. 1. F 462

OLDHAM CORPORATION WATER WORKS.

Tenders are Invited for the following:—

One HORIZONTAL ENGINE, with 2 in. starting valve, 9½ in. cylinders by 16 in. stroke, with 5 ft. dia. C.I. Fly Wheel with Governors, etc., and cast iron bed plate, 8 ft. 8 in. long, together with feed pump with 1 in. ram, with necessary syphon and exhaust taps, on stone foundation 10 ft. by 2 ft. 8in., with iron fencing.
One VERTICAL BOILER, 8 ft. by 2 ft. 9 in. dia., with Injector, Safety Valves, Gauge Taps, etc.
One STONE CRUSHER, by Robert Broadbent, Stalybridge, with two 5 ft. fly wheels, driving pulley, 36 in. by 7 in., with 21 in. jaws.
The Machinery and Crusher to be removed by and at the expense of the person tendering.
For permission to inspect the Machinery and Crusher, applicants should apply to Mr. C. J. BAILEY, Engineer, Plethorne, Near Rochdale.
Offers for the material should be addressed to MR. ERNEST PARRY, Commercial Superintendent, Water Office, Oldham, and sent not later than the morning of Tuesday, the 6th of April. F 543

CLYDE LIGHTHOUSES TRUST.

The Trustees invite

Enquiries for the Sale or Hire of their DREDGER, "WILLIAM H. RAEBURN" which is in excellent order. The Dredger is at present in the West Harbour, Port-Glasgow. It is capable of dredging 600 tons per hour at 42 feet depth, self-propelling, speed 5 knots; two sets of buckets large and small.

Further particulars of the vessel from Messrs. D. & C. STEVENSON, Civil Engineers, 94, George Street, Edinburgh.
Enquiries for sale or hire to be made to the undersigned.

J. F. ANDERSON, Clerk to the Trustees.
137, St. Vincent Street, Glasgow,
11th March, 1920. F 377

TO ENGINEERS AND OTHERS.

The Metropolitan Asylums Board invite

Tenders for Installation of NEW STEAM BOILER, IRONING MACHINE PIPEWORK and ENGINEERING WORK for LAUNDRY, at Princess Mary's Hospital, Cliftonville, Margate, Kent, in accordance with Drawing and Specifications prepared by Mr. T. Cooper, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Drawing, Specification and Form of Tender may be inspected at the Office of the Board, Embankment, E.C. 4, on and after Ten a.m., on Friday, 26th March, 1920, and the Drawing, Specification and Form of Tender can then be obtained upon payment of a deposit of £1. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender and after the Specification and the Drawing have been returned.
Tenders, addressed as noted on the Form, must be delivered at the Office of the Board, not later than 2.30 p.m., on Wednesday, 14th April, 1920.

By Order, DUNCOMBE MANN, Clerk to the Board. F 518

CORPORATION OF GLASGOW.

TRAMWAYS DEPARTMENT.

ELECTRIC GENERATING PLANT FOR SALE.

The Tramways Department of the CORPORATION OF GLASGOW are prepared to receive

Offers as Scrap or Complete

Unit for the undernoted Plant at their Pinkston Power Station, which is being superseded by Turbine Sets:—
One 2000 Kw. Three-Phase, Musgrave 25 Period STEAM ALTERNATOR SET, 7½ r.p.m., complete with Condenser, Pumps, Piping, etc.
Specification of the Plant, Conditions of Sale, and any other information desired, can be obtained on application to MR. JAMES DALRYMPLE, General Manager, 4d, Bath Street, Glasgow. Sealed Offer for the Plant, marked on outside "Tramways—Tender for Pinkston Plant for Sale," to be lodged with the Subscriber on or before Tuesday, 30th March, 1920.
The highest or any offer may not be accepted.

J. LINDSAY, Town Clerk.
City Chambers, Glasgow.
16th March, 1920. F 441

COUNTY BOROUGH OF SUNDERLAND.

ELECTRICITY WORKS EXTENSIONS.

The Corporation are prepared to receive

Tenders for—

SECTION A.—The SUPPLY and ERECTION of TWO WATER TUBE BOILERS, with Integral Superheaters, Mechanical Stokers, Vertical Cast-Iron Tube Economisers, Steel-plate Chimneys, etc., etc.
SECTION B.—The SUPPLY and ERECTION of ONE 1000 KW. ROTARY CONVERTER, 5000 volts, three-phase, to 550 volts, D.C.

Specification and Form of Tender for either Section may be had on application to the GENERAL MANAGER, Electricity Offices, Dunning Street, Sunderland, upon payment of a deposit of £1, which will be returned after a bona fide Tender has been received and opened.
Tenders, endorsed "Electricity Works Extensions," and addressed to the undersigned at the Town Hall, Sunderland, to be delivered not later than first post on Wednesday, 28th April, 1920.
The Corporation do not bind themselves to accept the lowest or any Tender.

H. CRAVEN, Town Clerk.
Town Hall, Sunderland,
22nd March, 1920. F 556

MUNICIPALITY OF BLOEMFONTEIN (SOUTH AFRICA).

APPOINTMENT OF CITY AND ELECTRICAL ENGINEER.

Applications are Hereby Invited for the above POSITION from men of energy and ability, possessing a wide knowledge of Municipal undertakings, including the Design, Construction and Maintenance of Waterworks, Electric Power Station and Distribution, Tramways, Drainage, Sewage Disposal, Roads and Bridges, Stormwater, Surveys, Housing and Town Planning, Buildings and Bye-laws, Abattoir and Cold Storage, Destructor, Laundries, Public Baths, Fire Equipment and Town Valuations.

The salary offered is £800 per annum, rising by annual increments of £50 to £1000 per annum, with free transport. Three years' agreement; passage out paid.
Applications, stating age, whether married or single, training, experience and when duties could be undertaken, together with copies of three recent testimonials and medical certificate of fitness, to be lodged with the undersigned not later than the 13th April, 1920.
The successful applicant will be required to devote the whole of his time to the services of this Municipality, and will be required to join the Pension Fund.

DAVIS & SOPER, LTD., Agents of the Municipality of Bloemfontein. 54, St. Mary Axe, London, E.C. 3.
22nd March, 1920. F 521

THE CARDIFF GAS LIGHT AND COKE COMPANY

Offer For Sale Compressed AIR AND STOKING MACHINERY by Messrs. West's Gas Improvement Co., Ltd., Manchester, comprising:—

One Two-Stage Air Compressor.
Two Compressed Air Scoop-Charging Machines.
Two Compressed Air Rake-Drawing Machines.
One Simultaneous Charging and Discharging Machine.

These machines are in good running order, well equipped with spare parts, and may be seen in action at the Grangestown Gas Works, Cardiff.
Latest date for receipt of offers, April 12th.

GEORGE CLARKE, General Manager and Secretary. F 431

APPOINTMENTS OPEN.

UNIVERSITY OF LIVERPOOL.

FACULTY OF ENGINEERING.

Assistant Lecturer and DEMONSTRATOR in Mechanical Engineering. The Council INVITE APPLICATIONS for this POST. Commencing salary £300 per annum, plus war bonus. Full particulars from the REGISTRAR. F 545

UNIVERSITY COLLEGE, NOTTINGHAM.

DEPARTMENT OF ENGINEERING.

Junior Lecturer in Mechanical Engineering WANTED to commence duties as early as possible in the Summer Term, 1920. Commencing Salary £250 per annum.

Further particulars and application forms may be obtained from the REGISTRAR, to whom they should be returned not later than April 12th. F 583

SUNDERLAND EDUCATION COMMITTEE.

JUNIOR TECHNICAL SCHOOL.

Applications are Invited for the POSITION of MASTER in the above School. Candidates must possess qualifications and teaching experience in Practical Mathematics and Experimental Mechanics, and some practical experience in Engineering.

Salary scale for graduates or those with equivalent qualifications, £180, rising by annual increments of £10 to £300, and then by increments of £15 to £370. Experience (including works experience), up to a maximum of 10 years, will be allowed to count in fixing the initial salary—*e.g.*, with 10 years' approved service the initial salary would be £300.
Forms of application, with three references or testimonials, to be returned to the undersigned by 29th March. The date must be stated on which the applicant could take up the position, if elected.

HERBERT REED, Chief Education Officer.
Education Offices,
15, John Street, Sunderland.
9th March, 1920. F 234

ROYAL AIR FORCE. BOYS' TRAINING CENTRES.

TEMPORARY APPOINTMENTS ON EDUCATIONAL STAFF.

The Services of a limited NUMBER of TEACHERS are REQUIRED for duty in the Boys' Training Centres at Halton, near Wendover, Bucks, and at Flowerdown, near Winchester, to give instruction in some or all of the following subjects:—English, Practical Mathematics, Mechanics, Heat and Electricity.

Rate of Salary, £250 to £300, according to qualifications and experience.
Teachers appointed to these temporary posts, whose work is well reported upon, and who have the requisite academic qualifications, will be considered for transfer to the permanent staff as vacancies occur.
Applications giving full particulars in regard to age, education, training and experience, together with copies of recent testimonials, should be forwarded immediately to the SECRETARY (T.2.B), Air Ministry, Kingsway, W.C. 2. F 384

Wanted, Flanger, Man accustomed to Heavy Marine Boiler work; good wages and steady employment can be guaranteed to a suitable man.—Address, F 481, Offices of ENGINEERING.

Wanted, Capstan Setter-Up used to Herbert Machines, for Commercial Vehicle Manufacturers in the North.—Address, stating previous experience, age and salary required, F 513, Offices of ENGINEERING.

Wanted, Cost Clerk, Young Man, 25-30, preferably trained in Engineering Works Office. Must be experienced in modern methods of keeping cost records, wages and material. Cardiff District.—Address, stating age, experience in detail, salary required, F 326, Offices of ENGINEERING.

Rate Fixer Required for Petrol Engine Works, near London. State age, experience and wages.—Address, F 382, Offices of ENGINEERING.

Rate Fixer.—A Large Engineering concern in the Manchester district. REQUIRE an experienced manufacturing ENGINEER to organise and control rate fixing department. Applications only invited from those who are conversant with latest manufacturing methods of electrical and mechanical details in machining and assembling operations. Good education and tactful disposition indispensable. State age, experience and salary required.—Address, F 350, Offices of ENGINEERING.

Required, Immediately, ASSISTANT for PUBLICITY DEPT., to undertake Machine Tool catalogue preparation. Advertising experience an advantage. Apply by letter, stating age, experience and salary required.—Address, GENERAL MANAGER, CHAS. CHURCHILL AND CO., LTD., 9-15, Leonard Street, E.C. 2. F 426

Assistant Chemist Wanted for laboratory of engineering works; experience in analysis of steels, cast iron, fuels, alloys, &c., desirable.—Apply, BUSTON & HORNSBY, LTD., Lincoln. F 546

Chemist.—Assistant, with Experience of analysis of iron, gunmetals and fuels, REQUIRED by Works Laboratory, near Newcastle-on-Tyne. Age about 21. Starting wage £3 weekly. Position offers prospects of advancement and knowledge. Replies will be treated in strictest confidence.—Address, with fullest particulars, F 439, Offices of ENGINEERING.

Storekeeper Required by a Gold Mining Company in West Africa. Must have thorough knowledge of Mining and Engineering Stores. Term of service 12 months on the property under agreement. First-class passages, simple quarters, and allowance for travelling expenses provided by the Company.—Write, stating age, giving full particulars of past experience and salary required, enclosing copies of testimonials, BOX 561A, SMITH'S, 21, Bush Lane, E.C. 4. F 530

Assistant Buyer Required. One used to central purchasing preferred. Must have good knowledge General Engineering requirements.—Address, F 535, Offices of ENGINEERING.

Recorder Wanted for Engineering Drawing Office of large Manufacturing Company in the Midlands. Applicants must have extensive experience and been in charge of a modern system for keeping all Drawing Office records, including card indexing of drawings, &c.
Permanent position for suitable man.—Address, stating age, experience, and salary required, F 571, Offices of ENGINEERING.

Works Superintendent Required by the D.P. Battery Co., Ltd., Bakewell.—Applications to JOHN WADDELL, Manager. F 510

Wanted, Night Shift Machine SHOP SUPERINTENDENT for large Commercial Vehicle Manufacturers in the North. Must be first-class man used to up-to-date methods and a knowledge of all classes of machines.—Address, stating previous experience, age and salary required, F 514, Offices of ENGINEERING.

Engineers' Manager Required by well-known London Company, to take complete charge of London end of subsidiary company operating in the East. Must have sound commercial experience, large engineering knowledge, and also be a capable buyer. Excellent prospects for the right man.—Apply by letter, stating age, experience and salary required, BOX A.12, SMITHS PUBLICITY SERVICE, LTD., 173, Great Portland Street, W. 1. F 495

Works Manager Required by Midland Firm. Applicants must have thorough knowledge of modern methods, preferably in machine tool manufacture. State age, experience and salary required.—Address, F 517, Offices of ENGINEERING.

Leading Progressive Engineering Firm REQUIRES immediately an EXPERIENCED ENGINEER to represent them in the North of England. Must be well educated, preferably at a Public School, and have works, drawing office and commercial experience. The position offers considerable possibilities to the man capable of handling a small sales staff and developing a well-established connection.—Address, F 361, Offices of ENGINEERING.

Assistant Engineer, (3rd grade) REQUIRED for the NIGERIAN GOVERNMENT RAILWAYS with possible permanency. Salary £300-£10-£350 and a war bonus of £120 a year. The question of increasing the salaries of Nigerian Government Officials on the withdrawal of the War Bonus is at present under consideration. Free single quarters and first-class passages. Liberal leave in England on full salary.
Candidates, 22-35, who have had experience as Civil Engineers on Railway Maintenance should apply in writing, not later than a week from the date of this advertisement, giving brief details of age and experience, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting M/Nigeria 8536. F 538

THE MUNICIPALITY OF SINGAPORE. STRAITS SETTLEMENTS.

ASSISTANT GAS ENGINEER.

The Municipal Commissioners of Singapore

Require an Assistant Gas ENGINEER, age 25-35, of sound constitution, and unmarried. He must have had a good technical education, a regular training as a Gas Engineer, with general all-round experience, including carbonising machinery, both in the design and in the construction of new works and in ordinary maintenance and in distribution. The appointment will be on agreement for three years with possible extension. The selected candidate must pass a medical examination as to his fitness for service in a tropical climate. A second-class passage will be provided by mail steamer, or a first-class passage by other steamer, with half-salary during the voyage out. The salary will be 4680 dollars for the first, 4980 dollars for the second, and 5280 dollars for the third year, with a Duty Allowance of 720 dollars per annum, all paid monthly, the value of the dollar being two shillings and fourpence sterling. For the first year the salary will be equal to £630 as above, with an allowance for such transport as may be required on duty. Free unfurnished quarters will be provided in addition. Applications, stating age and place of birth, and giving details of education, training and experience generally, and in Carbonising Machinery, and stating when free, accompanied by copies (only) of testimonials, and also personal references, to be lodged with Messrs. C. C. LINDSAY & PIERCE, M.M.Inst.C.E., 180, Hope Street, Glasgow, Agents to the Municipal Commissioners (from whom further information may be obtained), not later than Wednesday, 31st March, 1920. F 351

H.M. BATTLE CRUISER "HOOD."

THE completion of the new battle cruiser Hood, by Messrs. John Brown and Co., Limited, Clydebank, marks the close of a period in naval history, and this fact remains even although the battle cruiser era may not be at an end—as some authorities would have us believe. The ship was originally one of a group of four, but the Hood was the only one to reach completion and become a unit in the Navy—the greatest unit in any navy at the time. The countermanding of the other three units followed the definite defeat of the German armies, which were only saved from annihilation by the anxiety of their military chiefs to accept any terms of armistice rather than face the discredit of a capitulation which they realised must be the inevitable results of a few weeks longer warfare. Once a safe peace was assured the Government stopped work on many formidable engines of war, the character of some of which will perhaps never be disclosed. Amongst the warships countermanded were the remaining cruisers of the "Hood" Class.

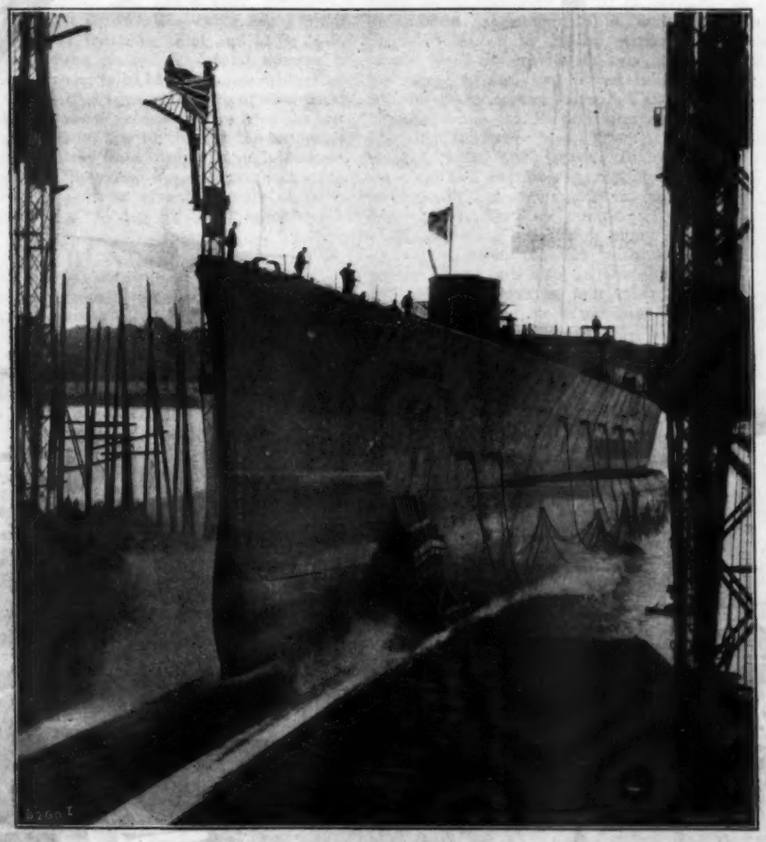


FIG. 1. THE LAUNCH

The construction of the Hood was begun at a time when the builder's yard was already employed to its utmost capacity in the building of all types of fighting ships, from the "E" Class submarines to the then largest battle cruiser, and the difficulties surrounding the initial design of a ship differing in many respects from anything hitherto built were overcome by the untiring efforts of the Director of Naval Construction and the Engineer-in-Chief and their staffs, supplemented by the great knowledge and experience of the Clydebank shipyard directors and their staffs. The task of building the ship was commenced in April, 1916, when the builders were furnished with sketches of the preliminary design supplying sufficient data to make possible the preparation of a definite scheme for the execution of the work. At this time, however, it was intended that each of the four firms building the ships should prepare a portion of the detail plans required. This arrangement for the subdivision of the work had to be modified when progress on the other three ships was first slowed down and then finally stopped. Messrs. John Brown and Co. were fortunate in having a building berth available for this immense ship and, further, in having the berth equipped with all the latest appliances for the rapid handling of the very heavy material as it became available for erection in place. These favourable conditions notwithstanding, the first keel plate was not laid until September, 1916.

The work of manufacturing the armour plating was divided amongst different armament firms, but the major portion of the heavy belt plates (weighing about 32 tons each), together with the conning-tower and other important items, was entrusted to Messrs. Brown, whose Sheffield establishment is so admirably adapted for such work, and the first of the main belt plates reached the shipyard in June, 1918.

The operation of launching the ship, itself a herculean task, was carried through without the slightest semblance of a hitch on Thursday, August 22, 1918, the launching ceremony being performed by the Hon. Lady Hood, widow of Rear-Admiral the Hon. Horace L. A. Hood, C.B., M.V.O., D.S.O. A view of the vessel as she took the water is reproduced in Fig. 1, and shows clearly some peculiarities in her structure to which we will refer later on. Another view of the launch is reproduced in Fig. 12, on Plate XXIV, whilst Fig. 10, on the same Plate, shows the stern of the vessel as she stood on the ways ready for launching.

The fitting out of the vessel at the builder's works was completed in January of this year, and on the 9th of that month the huge ship, representing the collaboration of many master minds in ship design, ship construction and offensive and defensive armament, passed down the Clyde to the open sea, preparatory to her being dry-docked for hull cleaning and steam trials. A view taken during this run is reproduced in Fig. 3, on Plate XXI, whilst Fig. 4 represents her being guided out of the dock with the aid of tugs. On the trial trips the turbines developed 157,000 S.H.P., the speed attained being 32 knots.

In many features the ship heralds a new departure, and radical changes have been effected with a view to increasing her efficiency as a fighting unit. The most obvious difference in her structure as compared with existing battle cruisers lies in the "bulge" or "blister," which secures the ship against effective attack by a torpedo. This bulge is well shown in Fig. 1, and also in Fig. 10, on Plate XXIV. The blister surrounds the main hull of the ship, and has been carefully proportioned so as to reduce to a minimum the additional resistance added to the hull. The design is due to Sir Eustace d'Eyncourt, K.C.B., Director of Naval Construction, with modifications suggested by the late Professor Hopkinson. Much thought has been brought to bear on the design of the details of this blister with a view to rendering the ship as near torpedo proof as possible. As an example, we may note that the subdivisional bulkheads have been so arranged that the energy of an external explosion is absorbed at the spot, thus preventing the piercing of the main hull should the outer hull be blown in by the explosion.

The armour has been disposed so as to provide the greatest possible protection against shell fire to the vitals of the ship. As an instance, it may be mentioned that the deck over the magazines is 3 in. thick. The side armour is fitted in three tiers, the lowest of which is 12 in. thick amidships, tapering to 6 in. and 5 in. forward and aft. Above the main 12-in. belt the middle and upper tiers are respectively 7 in. and 5 in. thick, whilst the conning-tower armour is 11 in. in thickness.

The main armament of the ship consists of eight 15-in. guns, all on the middle line. Each pair of guns is mounted in an armoured barbette. The disposition of the forward guns is clearly shown in Fig. 4, whilst the operation of shipping one of the 15-in. guns is represented in Fig. 2, page 398. The barbette armour is 12 in. thick, and the gun shields are 15 in. thick in front and 11 in. thick at the sides. The secondary armament consists of twelve 5·5-in. guns, five of which are mounted on each side of the vessel on the forecastle deck, the remaining two being mounted on the top of the superstructure. All these 5·5-in. guns are protected by gun-shields forming an integral part of the mounting. In addition there are four 4-in. anti-aircraft guns, also mounted on the superstructure. The 21-in. torpedo armament consists of two submerged tubes forward and four above water tubes placed on the upper deck abaft amidships.

The electric installation presents no very radical departures from previous Admiralty practice, but is interesting from the point of view of its magnitude, the usual number of electric generators installed in previous ships of this type having been increased to eight. An unusual feature of these generators is that they can supply either direct or alternating current as desired. The dynamos are all alike, but the prime movers vary, four being reciprocating engines, two geared high-speed impulse turbines, and the remaining two are eight-cylinder Diesel oil engines. One of the features of the electric installation is the use made of motor-driven pumps of the submersible pattern. Two sizes have been fitted of respectively 350 tons and 100 tons capacity. These differ from previous electric pumping plants in that the motors are not only immune from damage through contact with water, but are actually dependent for cool running upon a free circulation of water through the motor, which is of the alternating-current type. Electric power, so far as it concerns its application to centrifugal bilge and fresh water pumps, ventilating fans, refrigerating and magazine-cooling machinery, searchlights, boiler-room lifts, ammunition hoists, motor generators, pneumatic transmission of messages, follows the usual Admiralty practice. Altogether about 360 motors, ranging from the ¼ brake horse-power motor for the small ventilating fans, to the 140 brake horse-power motors required for operating boat hoists, are fitted.

The means of communication supplied are

unusually complete, and all possible improvements resulting from experience gained in actual service during the war have been embodied in the apparatus installed, including a very large number of loud-speaking telephones which have been provided for all purposes. It may be interesting to mention that nearly 3,000 incandescent electric lamps have been installed, in addition to a very large number of electric fires and culinary apparatus, all of which, though individually requiring a relatively small amount of power, represent in the aggregate a very large amount of the circuit wiring.

Hydraulic speed-varying gearing has been employed to an unusually large extent for the operation of boat hoists, deck winches, warping capstans, and for the auxiliary steering gear. Altogether 11 motors are employed in driving machinery of this type, the special features of which are simplicity of control and a large range of speed variation and torque.

The accommodation provided for the Admiral and officers is of the usual style, and while there is nothing in the way of extravagance the great size of the ship has made possible an improvement of the cabins, ward-room and gun-room. The welfare of the men has been studied with great care, with the result that the living quarters of the Hood are unparalleled in any warship for comfort, spaciousness and equipment. The equipment of bath rooms, wash-places, &c., is of the most modern type. The galley and bakery are fired by oil fuel and coal is only required for the stoves in the officers' quarters.

An idea of the magnitude of the work involved in the construction of the vessel is conveyed by Fig. 11, Plate XXIV, which shows the placing in position of the propeller shaft brackets, each weighing 35 tons, and by Fig. 9, which shows the completed stern of the ship just before the launch.

The propelling machinery comprises four distinct sets, each driving one shaft, arranged in three engine rooms, the starboard outer engine and the port outer engine being in the forward engine-room, the port inner engine in the middle engine room and the starboard inner engine in the aftermost engine-room. The turbines are of the Brown-Curtis type, and each set of machinery consists of compound ahead turbines driving the propeller shafting through single reduction gearing. For use at cruising speeds a cruising turbine of the Brown-Curtis type is provided. This has a separate casing and can at will be connected to, or disconnected from, the main high-pressure turbine shaft, suitable clutches being provided to this end. At cruising speed this turbine is operated in series with the high-pressure and low-pressure turbines of the set. A reverse turbine is fitted within the low-pressure casing and rotates in vacuum when the ship is running ahead. Each of the four sets of machinery is complete in itself with its own condenser and auxiliaries, and can be used independently. One set is shown complete in Fig. 5, Plate XXII, and Fig. 7, Plate XXIII. The engine-room telegraphs, worked from the conning-tower, are arranged so that the starboard telegraph in the conning-tower actuates the two telegraphs on the starboard side, in connection with the starboard outer engine and the starboard inner engine, and similarly on the port side of the ship, so that, as far as the navigation of the ship is concerned, the vessel is equivalent to a twin-screw steamer.

Each high-pressure ahead turbine rotor consists of 10 wheels, of which the first and second are velocity compounded having two rows of blades each, and the remainder are simple impulse wheels. Each low-pressure ahead turbine rotor consists of eight wheels, of the simple impulse type. A view of one of these low-pressure rotors is given in Fig. 15, page 414. Each cruising turbine rotor has four velocity compounded wheels with three rows of blades on the first wheel and two rows on each of the others. The astern turbine for each shaft is incorporated in the low-pressure ahead turbine casing, as shown to the left in Fig. 5, Plate XXII, and consists of two velocity compounded wheels, each carrying three rows of blades.

The turbine casings are of cast-iron with the nozzle control valve seatings cast in the body. The rotor spindles are of forged steel, having a tensile strength of 34 tons to 38 tons per square inch. The wheels are of forged steel, of similar quality, and phosphor bronze has been used for the blades, which are of the usual impulse type. The blades have dovetailed roots, and the tips of the blades are supported by phosphor-bronze shrouding. The diaphragms are of cast-iron, with the nozzle blades of nickel steel (about 3½ per cent. nickel) cast in; an illustration is given in Fig. 16, page 414, which represents the seventh diaphragm of one of the low-pressure turbines. The diaphragms in the cruising turbines and the first diaphragm in the

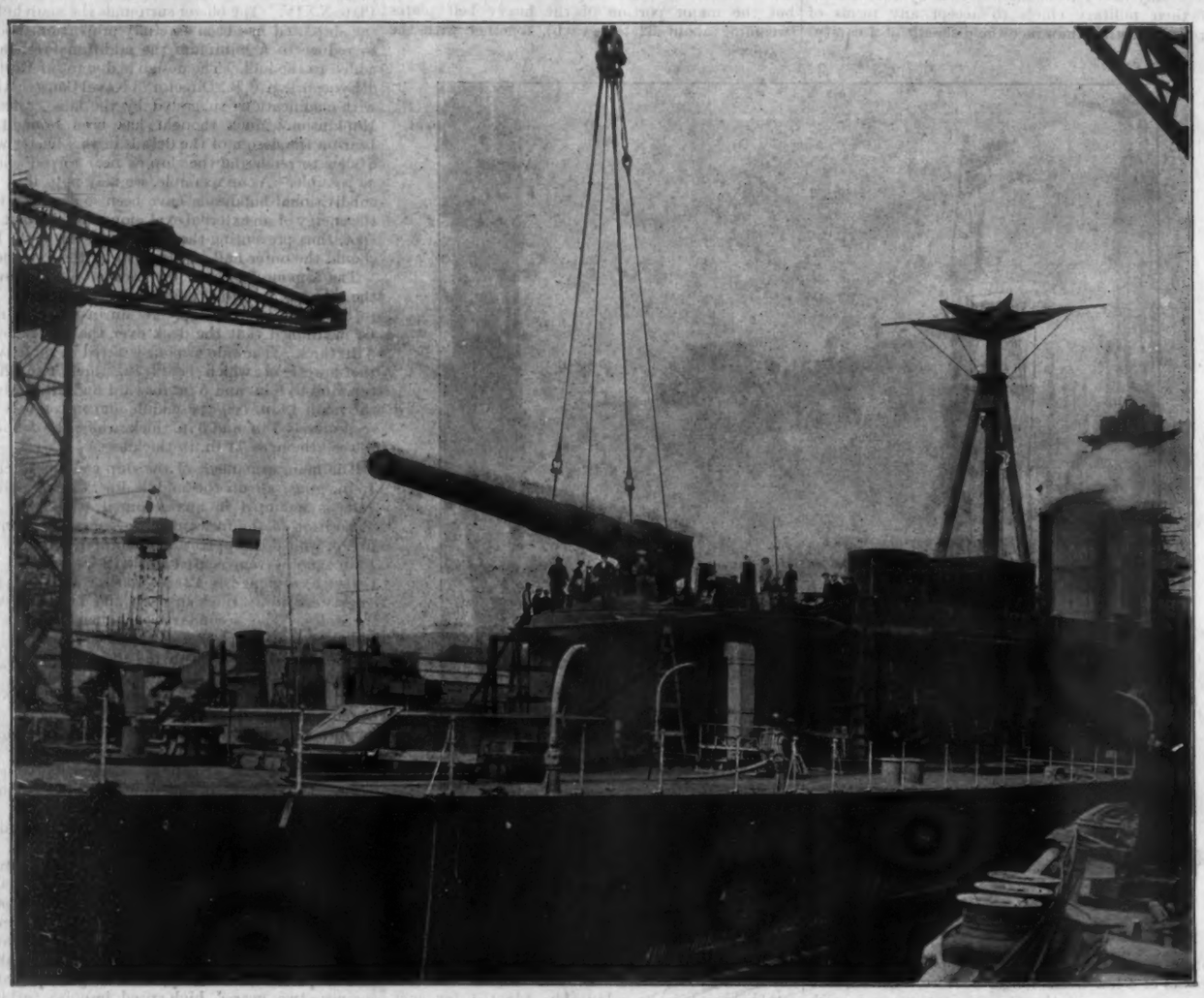


FIG. 2. LIFTING A 15-IN. GUN ON BOARD.

high-pressure turbines are solid, the remainder of the diaphragms in the high-pressure turbine, and those in the low-pressure turbines, being split. The spindle is made steamtight where it passes through the diaphragms by segmental serrated brass rings, kept up to their work by garter copper-coated steel springs in the cruising and the first diaphragm of the high-pressure turbines, and by sheradised coach springs in the other diaphragms of the high-pressure and in the low-pressure turbines. The glands are packed, as is usual in Brown-Curtis turbines, with carbon rings made in segments and held in position by springs. The high-pressure ahead forward end gland has eight carbon rings, the after end five, the low-pressure ahead four rings and the astern turbine four rings. The cruising turbine is fitted with five rings in each of the glands.

The condenser for each set is hung beneath the low-pressure turbine and has a total condensing surface of 24,400 sq. ft. The tubes are ⅝ in. in external diameter, 0·048 in. thick and 12 ft. 3½ in. long between tube plates. The total number of tubes per condenser is 12,144. The condensers are of the Weir's Uniflex type with shells of steel plates and angles, the steam entering direct from the low-pressure turbine and flowing through the condenser, while the circulating water passes through the lower tubes first and then the upper tubes. The condensers are designed to give a vacuum of 28 in. with sea water of 55 deg. F. and a barometer at 30 in.

Fig. 15, page 414, shows the bottom portion of a low-pressure casing with the rotor in place and the condenser slung from it. Each of the sets was tested thus, in order to make sure that when the machinery was in the ship and it was desired to lift the low-pressure cover to examine the rotor or for any other purpose, there would be no difficulty in re-entering the bolts of the longitudinal flange when the whole of the weight of the condenser was taken entirely by the lower half-casing. No trouble whatever was experienced in this connection during these tests. The weight of a condenser with the tubes filled with circulating water is about 70 tons;

The engines are designed to develop a total horse-power of 144,000, with about 210 revolutions of the propeller and about 210 lb. pressure in the control chest, with 28-in. vacuum in the condensers. The high-pressure turbine makes 1,500 r.p.m. at full power and the low-pressure turbine 1,100 r.p.m. As already stated, single reduction gearing is employed to reduce the revolutions of the turbine shaft to that of the propeller shafting. The pinion driven by the high-pressure turbine is 20·174 in. in diameter at the pitch centre, whilst that driven by the low-pressure turbine is 27·51 in. in diameter. The gear wheel has a pitch circle diameter of practically 144 in. These wheels are of the "built" type, and one is shown in Fig. 14, page 414, whilst on the balancing ways. Each wheel weighs about 46 tons. There are 392 teeth in the wheel, 55 on the high-pressure pinion and 75 on the low-pressure pinion. Hence, the ratio of reduction is 7·127 for the high-pressure pinion and 5·226 for the low-pressure pinion. The hobbing of one of these pinions is represented in Fig. 6, Plate XXII.

The thrust blocks on the rotor spindles, which also act as adjusting blocks for the rotors, are of the Michell type, as are also the thrust blocks on the propeller shafting. These latter measure 4 ft. 6 in. outside diameter of collar, with thickness of collar of 7½ in. This single collar takes the whole thrust on the shaft. The white metal surface of each thrust block amounts to 1,176 sq. in., both ahead and astern, giving a pressure on the thrust surface of about 200 lb. at full power ahead. One of these blocks is shown in Fig. 8, Plate XXIII, standing behind a completed block for a torpedo-boat destroyer. By the side of the completed block are shown two of the pad carriers, as well as a number of parts for similar thrust blocks. Fig. 13, page 414, illustrates one of these blocks with the cover removed showing some of the pads in position. The thrust shaft is 24 in. diameter, the intermediate shafting 24 in. diameter and the propeller shafting 28½ in. in diameter.

The propellers are of the solid type and are made of manganese bronze; they turn outwards when driving the ship ahead.

The main steam pipes are arranged in two runs along each side of the ship in the boiler rooms, one taking from each boiler room. They are of 19-in. bore. They are connected to the engine-room through two combined bulkhead and emergency valves on each side of the ship, and they are cross-connected in the forward engine-room. From the cross-connecting pipe are taken branches to the manœuvring gears in each of the forward engines, and also a 19-in. branch to the middle engine-room and a 19-in. branch to the after engine-room. Between the steam pipe and the regulating valve on each engine is fitted a separator.

Each set of main engines is provided with two main circulating pumps, the engines being of the enclosed forced lubrication type, and each pump having a 30-in. suction with a 31½ in. diameter impeller; two dual air pumps, the steam cylinder being 20 in. diameter by 20 in. stroke, the wet pump 36 in. diameter by 20 in., and the dry pump 38 in. diameter by 24 in. stroke; two grease extractors of the gravitation type, a direct contact feed-water heater, two forced lubrication pumps and one water service pump. There is, moreover, in each of the middle and after engine rooms an auxiliary condenser of 5,330 sq. ft. of condensing surface, with 5,390 tubes. In connection with these are two auxiliary circulating pumps of 18 in. suction and discharge and 27 in. diameter impeller, and two auxiliary air pumps. For the plummer blocks, a forced lubrication pump is fitted in the aft engine-room, together with a water service pump. There are also, in the engine rooms, six fire and bilge pumps, four oil-fuel tank pumps, a general service air compressor and four fresh water pumps.

The distilling machinery is situated in the middle and after engine-room. In each engine-room is a set "A" and a set "B." Each set "A" consists of two 80-ton evaporators and one distiller, and can be used for supplying water for the ship's use or make-up feed water for the boilers. Set "B" consists of one 80-ton evaporator with a vapour pipe connected only to the auxiliary condenser in the engine-room in which it is situated, so that it is used entirely for boiler make-up feed.

The steering engines are situated in the after engine-room and are two in number. Each consists of three cylinders, with direct-acting engines 17 in. diameter by 14 in. stroke, worked by a hydraulic telemotor. In the middle engine-room a reciprocating electric generating set is installed, the engines having cylinders 14½ in. and 24 in. in diameter by 9 in. stroke, coupled to one 200-kw. generator. A similar set is situated in the after engine-room.

Steam is supplied by 24 Yarrow-type small-tube boilers, burning oil fuel, situated in four compartments, each having six boilers. The working pressure is 235 lb. per square inch, and the heating surface per boiler 7,290 sq. ft. There are two funnels, each serving two boiler rooms. Each of these measures 24 ft. 6 in. by 18 ft., with an outer casing at a distance of 6 in. from the funnel proper. The distance from the lower burners on the front of the boilers to the funnel top is about 100 ft. There are 16 oil-fuel pressure pumps, four in each boiler room; these are all 12-ton pumps except two in the foremost boiler room, which are 24-ton pumps and are used for transferring oil fuel as well as for feeding the fires.

Each boiler room is fitted with six fans and engines. The fans have 90-in. impellers, and engines have cylinders 9 in. in diameter by 7 in. stroke. They are of the enclosed forced-lubrication type. The Weir's feed pumps have 15-in. and 10½-in. cylinders by 22 in. stroke, all of the same design. Six of these are fitted in each boiler room, four to act as main feed pumps and two as auxiliaries.

THE INSTITUTE OF METALS.

(*Concluded from page 372.*)

THE REMOVAL OF INTERNAL STRESS IN 70 : 30 BRASS BY LOW TEMPERATURE ANNEALING.

THE second paper taken on the morning of Friday, the 12th inst., was on "The Removal of Internal Stress in 70 : 30 Brass by Low Temperature Annealing," by H. Moore, O.B.E., B.Sc., F.I.C., and S. Beckinsale, B.Sc., A.I.C. It was read in abstract by the former. It said that the authors had carried out a series of experiments to determine the temperature range within which internal stress may be removed from cold worked 70 : 30 brass without serious reduction of hardness. Cups spun from sheet and initially in a state of high internal stress were annealed at temperatures ranging from 200 deg. to 325 deg. C., for periods of one minute to 120 hours; they were then treated with a mercurous nitrate solution, which caused stressed brass to crack. Samples of cold-rolled strip of Brinell hardness, 90, 120, 165 and 200 were annealed together with the spun cups. The hardness of the strips was determined before and after annealing. Internal stress was removed from spun cups in five hours at 250 deg. C., in 1 hour at 275 deg. C., in 20 minutes at 300 deg. C., or 5 minutes at 325 deg. C. Strips of initial hardness of 200 were appreciably softened by each of these treatments, but the hardnesses not exceeding 120 were not reduced at temperatures up to 300 deg. C. Strips of initial hardness of 165 began to soften slightly in 2 hours at 275 deg. C., or 20 minutes at 300 deg. C. The hardness of fully annealed 70 : 30 brass was about 50 to 60, and a hardness exceeding 165 was rarely if ever required in cold-worked brass. The effect of low-temperature annealing was a distinct though small increase in hardness. We reproduced this paper on page 393 *ante*.

Dr. Rosenhain, who spoke first, said the paper was not one which lent itself much to discussion. He thought the term "stress cracking" was not a suitable one to use, and he suggested "time cracking." The authors thought that when the material did not crack there were no internal stresses, these having been removed, but the point had to be proved. He asked whether they had taken a strip, had stressed it, and had treated it with mercurous nitrate. Information as to this would form a valuable addition to their facts.

Dr. Hatfield said he had read the paper with great interest; he entirely agreed with the author's findings, and also with Dr. Rosenhain's remarks as to "the samples being free from internal stresses." The authors had, however, intimated that these were too low to produce season cracking. He (the speaker) disagreed with the authors on that point only. He showed slides illustrating his own experimental work and pointed out the variations occurring in the metal by heat treatment, whereby he confirmed the authors' findings. He also gave the following figures of tensile strength and elongation on specimens pulled rapidly, at a medium speed and at a slow speed, using steel, brass thoroughly annealed and duralumin:—

—	Rapid.		Medium.		Slow.	
		%		%		%
Steel	8"	28[T] & 54	2' 20·28[T]	& 38	1 hour 28[T]	& 33
Brass	15"	19·4 & 64	160" 19·81	& 67	2 hours 30·9	& 63
Duralumin ..	5"	28·5 & 14	72" 29·01	& 14	84' 29·53	& 14

Admiral Goodwin understood that there was a possibility of removing the internal stress from these alloys without reducing their hardness. Admiralty condenser tubes before they were put in the condensers were under stress, and interesting results would be obtained by tests made of the tube packed, treated, and packed again.

Mr. Moore, in the course of a brief reply, agreed with Dr. Rosenhain, that the paper was not one which lent itself much to discussion. With regard to the term "time cracking," suggested, he asked that a better term be proposed, since he was not quite sure that time was a real factor to come into play. He was afraid the paper was, on the other hand, one which lent itself to criticism, and when it stated the complete removal of stress, there was, perhaps, some small stress left in the material. But the authors had removed, they thought, the stress which led to season cracking. They hoped to deal later with the behaviour of the strip referred to by Dr. Rosenhain. The agreement of Dr. Hadfield's results with those in the paper was satisfactory. The authors had steered clear of the amorphous theory and had confined themselves to practical figures. With reference to Admiral Goodwin's remarks they thought it would be possible to remove

the bad stresses from condenser tubes on the lines he had suggested.

A Model for Representing the Constitution of Ternary Alloys.

The third paper taken was one on "A Model for Representing the Constitution of Ternary Alloys," by Dr. Rosenhain, who read it in abstract and exhibited the model.

It describes a form of model by means of which the thermal-equilibria of a system of alloys, containing three metals, can be represented. The use of models for this purpose is well-known, but the majority of models hitherto constructed have consisted of solid pieces or blocks, shaped in accordance with the data obtained by observation, and fitted together to form a complete model. With this form a comprehensive view of all the various surfaces and boundaries cannot be obtained, since the inner surfaces cannot be seen through the bulk of the solid model. In the model described in the paper no solid blocks are used, but a construction of wires is adopted. The lines, curved or straight, along which the various equilibrium surfaces met one another are first set out by means of relatively stout wires. The surfaces themselves are then indicated by a net-work of finer wires, which, while indicating the shape and position of each surface, yet allow all the other surfaces, both below and above, to be seen at the same time. Distinction between the various surfaces is facilitated by the use of colour, each colour used being correlated to one of the phases which occur in the alloys. The model thus allows of a comprehensive view of the whole of the equilibrium conditions, and affords an insight into the constitution and behaviour of the alloys, which is not so readily obtained in any other way.

Mr. J. L. Haughton said Dr. Rosenhain had pointed out one use of the model. He (the speaker) thought it was not only very serviceable as an illustration when completed, but in the course of making it, it allowed one to see what progress had been attained. That also could be better realised from the model than by a section drawn on paper. He (the speaker) asked whether it would not be possible to have a model on the same lines to represent the mechanical properties of series of alloys, the various properties, tensile strength, elongation, &c., being as different sets of planes, and to obtain the correlation between the maximum strength, the elongation, etc., and the constitution of the alloys. Such models gave a much clearer conception of alloys than other means of illustration.

Professor Edwards thought the Institute owed their thanks to Dr. Rosenhain, even if he only induced those having a practical turn of mind to use the means thus put before them to study from the practical side the problems of metallurgy. The ternary systems will have to receive more consideration in future than they have yet received. By means of the simple method of the model it was possible to demonstrate clearly and simply exactly at what temperature and condition any change took place on cooling down. One could see that on looking through the wires. He (the speaker) did not suppose Dr. Rosenhain laid any special claim to originality in the matter, since ten years ago Dr. Andrews used a similar method for demonstration at Manchester University. The representations by models would be found of great advantage by all members.

Dr. Rosenhain in reply, and referring to Mr. Haughton's remarks, said that models could be made to represent any properties. He was not aware that models of wire had already been made for representing the constitution of ternary alloys.

Zinc Alloys with Aluminium and Copper.

The fourth paper was the one on "Zinc Alloys with Aluminium and Copper," by Dr. Rosenhain, Mr. J. L. Haughton, M.Sc., and Miss K. E. Bingham, B.Sc., which was read in abstract by the latter. The paper describes the constitution and mechanical properties of alloys of zinc containing copper up to 10 per cent. and aluminium up to 15 per cent. The constitution may be briefly summarised by saying that there is a ternary eutectic containing 4 per cent. of copper and 7 per cent. of aluminium, and two binary complexes, one the depressed eutectic of the aluminium zinc alloys, and the other formed from one constituent of the aluminium zinc and one of the copper zinc series. The ternary eutectic does not extend much beyond the alloys investigated. The rolling properties of the alloys have been studied, and it has been found that the addition of 1 per cent. of copper improves both the hot and cold rolling properties of zinc to a very marked extent. With the addition of more copper or aluminium, the cold rolling properties fall off rapidly. All the alloys are capable of hot rolling, but those containing much copper and aluminium become very brittle on cooling. The mechanical properties of the alloys are somewhat complex. The rolled material has, in many cases, a very high elongation if tested soon after being rolled, but in the course of a few months this falls to quite a low value; in one case from 70 per cent. on 2 ins. shortly after rolling to 1 per cent. after one year. Annealing at a temperature as low as 100 deg. C. has a similar effect, although heat treatment has no influence on cast specimens. The rate of loading in the tensile test has also a very marked effect; with rapid loading the maximum stress is very high and the elongation very low, whereas under very slow loading this is reversed. These observations can be explained on the assumption of the existence in the alloy of a considerable amount of amorphous material, produced by rolling. Other experiments confirming this hypothesis are described. For castings of such a nature that the small shrinkage, which occurs on ageing in most of the cast alloys, would not be deleterious, an alloy containing 3 per cent. of copper and 6 per cent. to 15 per cent. of aluminium is recommended. For rolled material, zinc containing 1 per cent. of copper appears to be very promising.

Dr. Rosenhain also added a few remarks, stating that the amorphous theory offered a satisfactory explanation and covered all the phenomena of the case. A graph in the paper showed in the return flow of the metal a close similarity with pitch and glass.

The discussion, which we need report only briefly, was opened by Dr. Hatfield, who congratulated the National Physical Laboratory for having carried out an excellent piece of constructive work. This work required doing and it could not be better done than by the N.P.L. But he refuted the authors' statements in the paper as to the phenomena referred to being explainable by means of the amorphous theory. He also found that their comparison with the action of glass and pitch was a loose one. As an alternative, the authors had the resources offered by metallography, and had no need whatever to have recourse to the amorphous theory for explaining the behaviour of the alloys they had dealt with.

Professor Turner called attention to the close analogy between the alloys in question and iron carbide.

Dr. Rosenhain confirmed the importance of the amorphous theory as the one to explain the phenomena alluded to, and maintained that the behavious of pitch and glass could be stated in comparison.

Tin-Phosphorus Alloys.

The last paper taken on Friday morning dealt with "Tin-Phosphorus Alloys," by Mr. A. C. Vivian, B.A., A.R.S.M., A.I.M.M., who read it in abstract. This was a detailed technical paper in which the author explained how he had prepared the alloys and prepared the specimens, he also explained their behaviour, and gave other characteristics.

Mr. J. L. Haughton congratulated the author for the interesting and complete way in which he had treated a difficult subject.

Admiral Goodwin invited further criticism on the paper by correspondence.

The first paper taken on the members reassembling on the afternoon of Friday, the 12th inst., was the one contributed by W. C. Hothersall, M.Sc., and E. L. Rhead, M.Sc., F.I.C., on

Some Notes on the Effects of Hydrogen on Copper.

It was read in abstract by Mr. Rhead. We reproduced it on page 391 of our last issue. The paper had relation to experiments on the effects produced on copper by passing hydrogen through the molten metal of differing degrees of purity varying from electrolytic copper to copper containing up to 0·4 per cent. arsenic and 0·4 per cent. sulphur. The authors found that while sound castings cannot be obtained from copper melted under carbon and not otherwise treated, sound castings can be obtained from metal treated with hydrogen at or above 1,110 deg. C., which has been allowed to solidify in the crucible after treatment and re-melted. Such copper retained much hydrogen. Analysis showed that the atomic amount of hydrogen retained was actually greater than that of other impurities, the effects of which were generally recognised. Micrographs of the treated metal showed that the effect of the hydrogen was to cause the sulphide and arsenide contents to be completely segregated in the envelopes surrounding the granules of copper, thus accounting for the increased electrical resistance which they found in hydrogenised copper.

The discussion was opened by Mr. J. Dewrance, who complimented the authors on the very interesting features they had pointed out in the refining of copper. He hoped they would pursue their investigations and give still further results. The passing of hydrogen through copper was a laboratory experiment and not a practical every-day process. He (the speaker) had passed hydrogen through copper to reduce the oxygen content, and he would have liked the authors to give the effect of hydrogen upon the content of oxygen, for some results obtained by them in regard to purity may have been due to the removal of oxygen. Small percentages of phosphorus had also a marked effect, and the effect of phosphoric acid was practically the same as that of hydrogen. He (the speaker) added that he would be very glad to use the influence he had with smelters of copper to aid in the carrying out of trials on the lines suggested by the paper. The inclusion of gases in copper was a subject which required more research and he again expressed the hope that the authors would continue their work.

Mr. F. Johnson said there appeared to be no determination for oxygen in the paper, and that was one of the most important things to do. In re-melting there seemed to have been every chance for the oxygen to be absorbed; on considering the authors two micro-sections in Fig. 7 and Fig. 8 (see page 392 *ante*) the former not treated and the latter treated by hydrogen, and probably re-melted, there seemed to have been oxygen absorbed. He thought the authors should have, also, made a differentiation between cuprous oxide and cuprous sulphide.

Mr. Rhead in replying, and with regard to the absence of determination of oxygen, said that in all coppers not remelted that determination was unnecessary because of the treatment with hydrogen. With reference to the segregation of the sulphide globules in the outer envelope, he had no hesitation in saying that they were sulphide and were forced to the outside envelopes. The effect of phosphorus was to prevent oxidation. With the use of hydrogen the gas in the metal was eliminated during solidification.

The Effect of Progressive Cold Drawing upon Some Physical Properties of Commercially Pure Copper.

The second paper taken dealt with "The Effect of Progressive Cold Drawing upon Some Physical Properties of Commercially Pure Copper," by W. E. Alkins, M.Sc., who read it in abstract. Its object was to give a detailed account of the effect of progressive cold work upon the tensile strength, specific gravity, elongation and scleroscope hardness of copper of the highest degree of purity commercially attainable, as drawn down into wire in the usual manner. It was found that each of these properties varied in an analogous fashion as the reduction in area increased; the tensile strength and scleroscope hardness increased, the specific gravity and elongation diminished, with increasing amounts of cold work. In every case the curve showing the variation in any given property with increasing reduction in area consisted of two branches connected by a short intermediate portion over which the change became very small over a limited range of reduction.

With heavy instead of light drafting the break in the curves occurred at approximately the same percentage reduction in area, but when the metal was thoroughly annealed previously to the drawing the break set in at a somewhat earlier stage and at a lower tensile strength. The agreement between the tensile strength and the elongation, and between the specific volume and the scleroscope hardness, was throughout very striking. No attempt was made at giving a theoretical interpretation of the results obtained. The paper concluded with a brief reference to several points of interest which had arisen during the progress of the work and to methods for the more strictly quantitative investigation of the whole problem.

This paper was taken in conjunction with one on

THE INFLUENCE OF COLD ROLLING ON THE PHYSICAL PROPERTIES OF COPPER,

by F. Johnson, M.Sc., who also read it in abstract. This dealt with a further investigation of the changes in properties resulting from the uninterrupted cold-rolling of electrolytic wire-bar copper, commencing with a thickness of 1·5 in., and finishing with a thickness of 0·033 in., the number of passes being 17. The changes in tenacity, elongation, Shore and Brinell hardness, lateral spread and specific gravity were determined. By plotting these figures against percentage reduction of thickness it was found that there were at least two well-marked critical ranges of deformation over which the tenacity, elongation and hardness remained constant, whilst the width of the strips also remained constant, no lateral spread being noticeable. There were marked indications of other critical ranges; also a few determinations of the elastic limits (or limits of proportionality) were made, and they indicated a marked rise over the critical ranges. The specific gravity determinations yielded no collateral evidence of the existence of the critical ranges, but concordant results were rarely obtained. By taking the tests always from the centre of the rolled strips more regularity was obtainable, and an increase was observable which was steadily maintained up to 87 per cent. reduction. The author drew attention to the inequality of distribution of strains in the rolled strips, both laterally, vertically and longitudinally. Test pieces taken from the centre always yielded the highest results for hardness and tenacity. Suggestions were made with a view to obviating experimental difficulties in future work. Micrographs of the series showed a progressive flattening and thinning of the crystal grains until a typically laminated structure was obtained in which the grains appeared as parallel laminae. Space was given to theoretical considerations, and the author suggested that the crystal grains were forced by the rolling process into a homotropic arrangement in which slip could occur more smoothly and readily under tensional forces over the critical ranges than at other stages of deformation where tensional and compressional forces were both in action more or less equally.

Mr. Alkins said he had read Mr. Johnson's contribution with great interest, his micrographs forming an important part of his work. Cold rolling appeared to be irregular in comparison with cold drawing, and, therefore, a certain latitude had to be allowed for in the results. In regard to specific gravity determinations, he (the speaker) emphasised the accuracy with which they had to be carried out; the accuracy was comparable with that required of atomic weight determinations, and he could not make more than six specific gravity determinations in four hours.

Mr. Johnson stated he would reply in detail to Mr. Alkins' paper after he had read it over. Mr. Alkins, dealing with the term "complete annealing," attempted to give a definition for it, and said that copper wires may be said to be completely annealed in respect to tensile strength when the tensile strength is no longer diminished by prolonging the time of heating at constant temperature, and the definition might be varied by the substitution of any physical property for the tensile strength. He (the speaker) thought one might conform with that definition and over-anneal. Mr. Alkins had also stated that the wires were drawn and not forced through the dies; but he (the speaker) would suggest that they were forced through the dies nevertheless, and thought the author was perhaps obsessed by the extrusion process. Although the wire was not pushed through it was forced through, and the author would have to elaborate the point.

Mr. F. Tomlinson thought that in reading the two papers before the meeting the former papers by the authors should also be taken into consideration. Mr. Alkins had said there could be little doubt that the paramount necessity of the moment was for further data rather than for an explanation of the few facts so far established, which were far too scanty to allow of the founding upon them of any theoretical considerations. He (the speaker) agreed that the field was a large one, and he hoped Mr. Alkins would continue his work; it would take him a long time. It would, however, be helpful if we could have a proper explanation of the particular phenomenon caused by the various treatments. It would, further, be an advantage if there were more co-operation among the workers, also, he might add (alluding to the different views held in regard to the amorphous theory), between the gentlemen who approached those problems from the purely scientific side.

Professor Edwards, referring to Mr. Johnson's curves said the breaks pointed out in them were what one would expect; they indicated that in the process of rolling, the work at some given time was more on the outside than on the inside of the bar, Professor Edwards also referred to the amorphous theory and said the more he thought about the matter the more he felt that we should have to modify our views of that theory; he asked Dr. Rosenhain and others to bring the point under critical survey. Cold work might introduce the amorphous phase.

Professor Turner sympathised with Mr. Alkins in regard to the difficulty of taking specific gravities; he had to deal with very small weights and great care had to be exercised.

Mr. O. W. Ellis thought Mr. Alkins' method of plotting curves a most satisfactory one, and found his hardness figures interesting.

Admiral Goodwin suggested that much that was said in the two papers might apply to turbine blading; metal was required better suited to the needs in this respect than much of the metal now available.

Mr. Alkins, with reference to Mr. Johnson's remarks, said he had ventured to give something in the nature of a theoretical explanation of the term "complete annealing," but must leave the matter to others who were more experienced than he. His samples were taken parallel to the direction of drawing. Scleroscope determination bore relation to the elastic phenomena. The breaks in Mr. Johnson's curves were hardly due to experimental errors in the ordinary sense, but more probably to irregularities in the metal in the cold-rolling work; in drawing there was no opportunity for the metal to slip. In getting out his specific gravites he had not considered the possible occurrence of air bubbles nor that of solution of metal on the surface.

Mr. Johnson said that from Mr. Alkins' remarks and from points which came out in the course of the discussion it might perhaps be thought that his own work had been slavishly carried out because Mr. Alkins had taken up his work dealing with cold drawing, and that Mr. Alkins' former paper had suggested his own on cold rolling. That might be true in a sense, but he might add that several years ago he had noted down the question for dealing with it at some future time. He (the speaker) did not attribute any great importance to the steps in his curves, except in the case of two, the others being probably due to irregularities in the metal in the course of being rolled. In regard to specific gravity tests, he (the speaker) said that if he could carry out two in 3 hours that was as many as he could do. He referred, with regard to this point, to the care which had to be taken in cleaning the specimens, in noting the temperature of the water, &c., all of which he did not state in detail through lack of space. He could not accept the suggestion that had been thrown out to the effect that the steps or breaks in his curves might be due to an experimental error. He had a great admiration for the work that had been done in regard to the amorphous theory, and for the tenacity and skill which had been shown with a view to establishing that theory.

THE STUDY OF THERMAL ELECTROMOTIVE FORCE AS AN AID TO THE INVESTIGATION OF THE CONSTITUTION OF ALLOY SYSTEMS.

This paper was read in abstract by the author, J. L. Haughton, M.Sc., who added that it dealt with the subject which would come forward at the next May meeting. It stated that the constitution of alloy systems was generally investigated by means of thermal analysis and the microscopic examination of annealed and quenched specimens. Useful information could, however, be obtained by the study of the physical and mechanical properties of the series, and the paper dealt with one of these, viz., the study of thermal electromotive force. The curves given, when the thermal electromotive forces of a series of alloys were plotted against the composition, were often very complex, but it could be shown that they were built up of branches which had one of three forms according to whether solid solutions or mechanical mixtures existed. The existence of compounds might be shown by breaks in the curves, or, in certain cases, by maxima or minima. The arrangement of the constituents in an alloy might have an effect on the thermal E.M.F. The theory of this was worked out, and the results of experiments with composite copper and nickel rods were given. In this case the E.M.F. against iron was nearly 50 per cent. greater when the copper and nickel were in the form of small discs in series, than when they were in the form of a bundle of parallel sheets. Practical details as to the methods employed in the determination of the E.M.F. for a series of alloys, together with a description of a simple apparatus designed for this determination, were given. The paper concluded with an appendix describing the various thermal effects, dealing principally with the recently-discovered Benedicks effects.

The next paper taken dealt with was on

IDIOMORPHIC CRYSTALS OF ELECTRO-DEPOSITED COPPER,

by W. E. Hughes, B.A., who read it in abstract. It stated that idiomorphic crystals of electro-deposited copper could be formed at will, if suitable conditions of deposition were adopted. It was found by the author that two requisites were: (1) Slow deposition of the metal, and (2) as little movement as may be in the solution. A suitable device was found to be a small cylinder of metal, slightly hollow at one end, suspended vertically in the solution between two anodes. The solution consisted of copper sulphate and perchloric acid. Photo-micrographs of crystals of copper so formed were given in the paper. The conditions obtaining when the deposition proceeded under the circumstances stated were shown to be analogous to those in which good idiomorphic crystals were formed in salt solutions, as shown by Moore's experience. And hence the author considered the formation of copper crystals and salt crystals to be governed by the same general laws of crystal formation. The work of Sieverts, Wippelmann and von Schwarz was considered in some detail.

Professor Edwards asked the author whether he had found it possible to get idiomorphic crystals in zinc, and if he could help in that matter his experience would be much appreciated.

The last paper on the list, a Note on the

POLISHING AND ETCHING OF ZINC FOR MICRO-EXAMINATION,

by H. H. Hayes, was taken as read. The author, in this note, stated that owing to the rapid increase in the industrial use of zinc in the form of thin sheet, it had been found imperative to develop a rapid method of polishing and etching this material for microscopical examination in order to study the effects of different methods of annealing. In the method described, the polishing was done with Globe polish on chamois leather. No water must touch the surface during or after polishing. The etching medium was fuming nitric acid, in which acid the specimen was immersed for 1 second and immediately rinsed in water and dried by a hot-air blast.

All the authors of papers received the thanks of

the meeting for their contributions as these, came up for discussion.

A vote conveying the thanks of the Institute to the Institution of Mechanical Engineers for the loan of their premises concluded the proceedings.

POSITIVE RAYS.

On Saturday afternoon last, at the Royal Institution, Professor Sir J. J. Thomson, O.M., President of the Royal Society, delivered the penultimate lecture of his course on the above subject.

He wished, he said, at the beginning of this lecture to say a word or two about the physical properties of positive rays. These rays consisted of atoms or molecules moving at speeds of the order of 2,000 miles per second. Hence, so far as the energy carried by them was concerned, they formed a sort of halfway house between the α rays shot out by radium with tenfold this velocity and ordinary gaseous molecules. The α rays were, we knew, positive rays of helium, and in virtue of their enormous velocity were able to get through solids of considerable thickness. It was of interest accordingly to know if the positive rays found in discharge tubes were capable of penetrating thin layers of solids. So far as he knew, Sir Joseph proceeded, the first experiments on this head were made by an American, Mr. Goldsmith, using sheets of mica less than $\frac{1}{2000}$ mm. in thickness. Such sheets he found were penetrated by positive rays of hydrogen atoms and by positive rays of hydrogen molecules. The most extensive series of experiments of this kind had, however, been made by Von Tragenberg, who sorted out his positive rays by electric and magnetic fields, as already explained, but used as his target a phosphorescent screen covered with thin gold leaf. Von Tragenberg found that three parabolas were still visible on the screen, the particles constituting the rays having penetrated the gold leaf. These three parabolas were those due respectively to the hydrogen atom, to the hydrogen molecule and to an atom which was either that of nitrogen or of oxygen, the separation of the parabolas with fields of the strength used by this observer being insufficient to distinguish between the two.

In some respects this method of determining the penetrative powers of the positive rays was almost ideal. In the first place, each parabola was due to the impact of one substance only, the different particles of which were, however, moving with widely different velocities. From the appearance of the screen it was possible to determine the point at which there was penetration of the gold leaf, and hence to deduce the minimum speed necessary to carry that particular kind of particle through. It could also be seen how the penetration varied with the specific weight of the particles. Von Tragenberg's result was that the thickness of gold leaf penetrated was directly proportional to the velocity of the particle. For atoms of hydrogen moving with a velocity of $2{\cdot}8 \times 10^9$ cm. per second (about 2,000 miles per second), he found that the thickness of gold leaf which would just not stop the particle passing through was $3{\cdot}6 \times 10^{-6}$ cm. Gold leaf of this thickness was not extravagantly thin.

There was, the speaker continued, much scope for further experiments of this kind, in which he thought it might be well to replace the phosphorescent screen by a photographic plate, as being easier to work with and yielding more definite results. Such particles as passed through the gold leaf were found, he might add, to have lost their charge.

He would now pass, Professor Thomson continued, to another property of the positive rays which was a source of considerable trouble to all who used discharge tubes in which a high vacuum was desired. All who had worked with such tubes knew that after a time metal from the cathode was found to have been deposited on the walls of the tube, making it impossible to see what was going on inside. This spluttering of the electrodes was produced by the impact of the positive rays, and was found only at the negative electrode. That it was due, as stated, to the impact of the positive rays was apparent from the fact that a stream of these rays directed on to such a deposit washed it away. These rays accordingly when they fell on a metal made it evaporate, and the vapour then condensed on the walls of the tube. The rate varied greatly with different metals, and the common use of aluminium for electrodes was due to the fact that, in most cases, it spluttered less than other metals and the tubes accordingly remained clean for a longer time. In some cases the deposit was formed very rapidly. With a cathode of cadmium, for instance, which was a fairly non-volatile metal, the effect was apparent after about one minute's use.

This property of the positive rays had proved of importance in many experimental investigations. At times the physicist needed a film of metal which should be at once coherent and yet semi-transparent. Such films could be produced by fixing a piece of glass near the cathode and passing the discharge. The particles evaporated from the cathode by the impact of the positive rays were condensed on the glass. Semi-transparent films

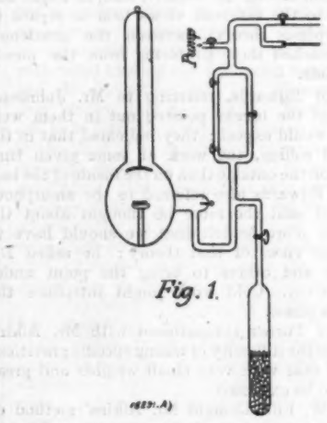


Fig. 1.

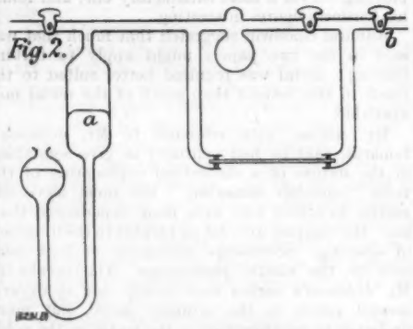


Fig. 2.

both of platinum and silver had been thus obtained, and the process was under the full control of the operator, who, by stopping the discharge at any point, could get any degree of transparency desired. The process had, he might mention, also been employed for artistic ends, very pretty effects being obtained by placing muslin near the cathode. In this case the metal was deposited on the fibres, the result being gold or silver lace, according to the cathode employed.

Returning to the severer aspect of this phenomenon, it was, the speaker said, of very considerable interest to compare the energy carried by a positive ray with that required to liberate a molecule from a metal. The latter could be calculated from the known heat of vaporisation. It thus appeared that the energy required to evaporate an atom of a metal was generally about equal to that acquired by an atomic charge of electricity in falling through $\frac{1}{10}$ volt. Hence, if the positive ray particle transferred its energy to a single molecule of its target, this molecule would be displaced if the positive particle had fallen through a very small fraction of a volt. As a matter of observation, however, it was found that unless the postive particles possessed energy equivalent to a fall through more than 500 volts there was no spluttering at all. In short, the phenomenon in question came in almost discontinuously when the potential difference between the terminals of the tube rose above a certain limit which for most metals was about 500 volts. Thus, although each individual molecule of cadmium needed for its evaporation energy equal only to the fall of an atomic charge through $\frac{1}{10}$ volt the colliding positive ray could not liberate from the cathode even one molecule unless it possessed about 10,000 times this amount of energy. The atoms on the target were, it appeared, so firmly bound together that the energy of any individual atom struck was distributed amongst its neighbours, so that no individual one received the full measure of the energy transferred by the impact. It thus appeared that when a positive ray hit the cathode it liberated the atoms in groups and not one by one. As an analogy Professor Worthington's experiments on the fall of drops into water might be brought forward. Professor Worthington found that the disturbance at the point of impact spread out. A kind of crater was formed beneath the drop. The walls of this rose and then broke up into fine spray. Probably something of the same kind occurred when a positive ray struck against a metal. The energy instead of being concentrated on the particle struck was distributed amongst a large group each of which in order to be liberated must receive at least $\frac{1}{10,000}$ of the energy of the ray, assuming that the latter had acquired the energy due to a fall through 500 volts. Spluttering was, moreover, very dependent on the nature of the gas in the discharge tube. The general result appeared to be that the denser the gas the greater the spluttering. As he had already stated, aluminium electrodes did not splutter much with air or hydrogen in the discharge tube. If, however, the gas in the tube were argon, aluminium spluttered freely, and he had an old tube containing this gas in which the glass around the electrodes was completely covered by a mirror of aluminium produced by spluttering.

Stark had shown that not only metals but quartz, mica, and, indeed, practically every substance could be disintegrated by the impact of positive rays.

He would now, Professor Thomson continued, go on to the use that could be made of the positive rays as a method of chemical analysis. As a first example, he would show the application of the method to the analysis of the gases liberated by metals and minerals when heated. Terrestial helium had first been discovered (though not by positive rays) amongst the gases driven off on heating a certain mineral. In this case, the spectroscope was used for analysing the gases, but the positive ray method was distinctly more delicate as a means of detecting the nature of the gases liberated. It was in such experiments advantageous to replace the ordinary methods of heating up the specimens by using an electric furnace of a somewhat special type. This consisted of a discharge tube having the cathode curved so that the cathode rays shot off were concentrated into a focus. A table was fixed just below this focus and on it was placed the substance to be heated. The temperature to which this was raised in the cathode ray focus was much higher than could be attained by the ordinary methods of heating. The apparatus was, he said, represented in Fig. 1 where the focus tube was shown on the left. The gases liberated from the mineral at the anti-cathode passed off through the tube visible at the top of the diagram to a receiver a Fig. 2, where they were stored over mercury. They could then be passed by alternative paths to the tube b which led to the discharge apparatus. In the lower of the alternative paths was interposed a long and fine capillary tube which was used when it was desired to maintain a continuous stream of gas into the positive ray apparatus. In this it was, as explained in a previous lecture, necessary to maintain a very high vacuum, and hence the supply of gas passing into the apparatus must not exceed that which could be pumped away continuously as fast as it entered the discharge tube. Quite large amounts of gas were liberated from minerals when thus heated. When, for example, a piece of mica was placed at the anti-cathode of a focus tube the amount of gas liberated in a minute or so was sufficient to increase the pressure in the tube from an original value equal to a small fraction of a mm. of mercury to a pressure equivalent to 2 or 3 m.m. of mercury.

The bulk of the gases liberated on heating minerals

was neither rich nor rare. Nine-tenths of the total was made up of hydrogen, carbon monoxide, or carbonic acid gas. It was the residue which was interesting from the chemists' point of view. Thus on heating practically any solid, and examining the gases liberated by the positive ray method, we got in addition to lines referable to elements already known, a line corresponding to an atomic weight of 3. This line was, he said, clearly shown in Fig. 3 (reproduced from our issue of March 12 last). In this case the substance bombarded by the cathode rays in the focus tube was potassium iodide. On the slide the topmost line was due to atoms of hydrogen, the next line to the hydrogen molecule, and then came a fainter line, due to some substance with an apparent atomic weight of 3. This line was obtained in practically all cases; in fact, he did not remember a single instance in which traces of it were not apparent whatever the substance bombarded by the cathode rays. With some substances, however, the line was much more prominent not nearly so great as it was with the vapour of phosphonium iodide.

In these cases the inference was that the line in question was due to triatomic molecules of hydrogen. A difficulty remaining, however, was that if the line were due to triatomic H (and he thought in some cases it undoubtedly was), why was it so rare? He had, Sir Joseph continued, worked for months with a tube containing H, and on not one of the photographs taken was there a trace of this line corresponding to H_3. If, however, a piece of mica were bombarded by the cathode rays, the line came out quite strongly in the positive ray photograph obtained from the gases liberated. It would seem therefore that some special conditions were associated with the formation of this molecule, which was closely connected with the absorption of gases by solids. As he had never bombarded any solid without finding traces of the line in question, he was driven to think that if the line was always due to H_3 then in all substances there must be

stance bombarded was a variety of fluorspar, non-crystalline, and having much the appearance of ferrous oxide. It was found amongst the cryolite deposits at Ivigtut in Southern Greenland, and contained traces of cerium. It was first noticed by Julius Thomsen, famous for his determinations of the heat liberated in chemical reactions, but had never even received a name.

When this substance was bombarded in the focus tube it yielded some very interesting gases including an immense amount of helium. In figure 5 the helium line was the third bright line from the top. The bright line above it was due to the hydrogen molecule and between the two was a faint line due to "3." Just between this and the helium line came another faint line, corresponding to an atomic weight of 3·5. It was a very faint line but quite distinct. A body with an atomic weight of 3·5 was a most unorthodox element. In general the elements had atomic weights which were nearly whole numbers and, indeed, Mr. Aston's recent de-

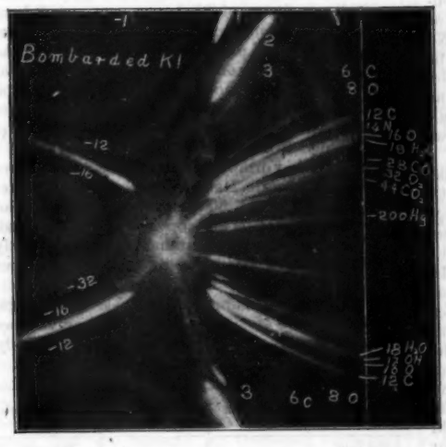


FIG. 3.

FIG. 4.

FIG. 5.

in the photograph than with others. The question arose as to what was its nature. The evidence seemed to show that in some cases at any rate the line was certainly due to a molecule compounded of 3 atoms of hydrogen and carrying a single charge, but it was not yet clear whether in addition to this there was not a particle of another kind than this complex of atoms, which also contributed to produce the line corresponding to an atomic weight of 3.

When ordinary minerals were bombarded the difficulty arose that we did not know precisely what they contained. If, however, we used vapours in our discharge tube we did know what we put into the tube, and hence if we get this new substance, it was probable that it was produced from the vapour put in. When the vapour was that of phosphonium iodide the "3" line was quite distinct, although not as prominent as in the gases derived from certain minerals. Since the vapour in question contained a trivalent constituent, it might be supposed that there was some connection between this trivalency and the formation of molecules consisting of 3 atoms of hydrogen. The photograph obtained with phosphonium iodide in the discharge tube was, he said, reproduced in Fig. 4. In this case the dispersion was so great that the line due to the hydrogen atom did not appear on the plate and the uppermost line visible was that due to the H molecule. Just below this line was a faint line due to particles of something with an apparent atomic weight of 3. The fact that this line appeared so distinctly when the vapour in the discharge tube was a compound of a trivalent element gave reason for concluding that in this case at any rate the line was due to the molecule H_3. When ammonia, a compound of another trivalent element, was examined in a similar way only traces of the H_3 line were visible, the quantity formed being for some reason traces of impurities corresponding to trivalent elements which formed the basis for the grouping together of 3 atoms of hydrogen. He did not know what chemical evidence there might be in support of such a conclusion.

This substance "3" was still given out after a bombardment continued daily for months. It even survived the repeated solution and recrystallisation of the salts used, and appeared in cases when the substance experimented with was supposed to be quite free from hydrogen. Once obtained, moreover, it was remarkably persistent; hence he did not think that it was an evanescent compound produced momentarily by the discharge. A long time was needed to clear "3" from a tube in which it had once made its appearance. The tube had to be washed out repeatedly and run for a considerable time before all traces of "3" disappeared. It would thus seem as if it got absorbed in the walls of the tube or by the electrodes. It was difficult to reconcile this behaviour with the view that it was formed by action of the discharge.

Helium also was often liberated when any salt was for the first time bombarded by the cathode rays, showing that this gas was stored up to a small extent in all solids. Unlike "3," however, it was gradually driven off and disappeared if the bombardment were long continued. Of course in such experiments it was necessary to make sure that the helium was not derived from air leaking into the apparatus, since the positive ray method was capable of detecting the amount present in 1 c.c. of air. Such a contingency was, however, easily guarded against, and in fact no helium line appeared unless there were present a salt under bombardment by the cathode rays, and the helium line was still to be found if this salt was fused and recrystallised.

Another line had been recognised on positive ray plates during the last few weeks. The substance terminations had shown that with the exception of hydrogen the atomic weights were all exactly whole numbers. Yet in the positive ray photographs of the gases derived from this peculiar variety of fluorspar we had always accompanying the line "3," this additional line corresponding to an atomic weight of 3½. The new line showed certain peculiarities. It was always accompanied by a considerable amount of secondary lines, as indeed was usually the case with "3." Since finding it on the plates obtained in the positive ray analysis of the gases from this peculiar type of fluorspar, the speaker had found, whenever "3" was present, traces of the new line on plates obtained with the gases from other minerals. In these cases, however, the line was always very faint, never comparable in strength with the line due to "3," and it was never present when "3" was absent.

It might be suggested that the line was due to an atom of ithium carrying two charges, but it was very hard to get a lithium line carrying even one charge. Again, it might be due to an atom of nitrogen carrying four charges; but in that case we might expect to find it common instead of rare. In fact it was difficult to account for by any kind of juggling between the atomic weights and the charges carried by the heavier kinds of atoms.

Treating the problem as a mere matter of arithmetic the line could be accounted for by a molecule consisting of seven atoms of hydrogen carrying a double charge, but the only evidence in favour of this view was that seven divided by two was equal to 3½.

THE LATE DR. DOLIVO-DOBROWOLSKY: ERRATA.—In our paragraph on page 352 of the issue of the 12th inst. two misprints require correction. Two (not 200) alternating currents differing by 90 deg. in phase will give a rotating magnetic field, and the distance Lauffen–Frankfurt is 200 km. (not 100 km.).

THE INSTITUTION OF MECHANICAL ENGINEERS.

A MEETING of the above institution was held on Friday last, at the Institution House, Westminster, the President, Captain Sankey, occupying the chair.

MECHANICAL STOKERS.

The formal business having been despatched, Mr. David Brownlie read an abstract of his paper entitled "Exact Data on the Performance of Mechanical Stokers as Applied to 'Lancashire' or Other Narrow-Flued Boilers." We commence the reprint of this paper in another part of this issue.

In opening the discussion, the President commented upon the labour involved in the making of the 80 trials with which the paper dealt, and in the collation and co-ordination of the results. The author's statement of results, and his comment that there was little measuring apparatus to be seen in boiler installations generally would come as a shock to many people.

Mr. G. B. Storie expressed himself as not clear how the smoke tests had been made. Five different degrees of black smoke were indicated in the paper. He had before him a chart printed by the Institution of Civil Engineers some years ago in connection with certain steam trials, in which a series of diagrams, numbered one to five, indicated the beginning of the shade of smoke. He considered that it would have made the matter clearer if Mr. Brownlie had adopted the same method. Mr. Storie had had a good deal of experience of the working of mechanical stokers and of hand firing, and some years ago had acted as advisory engineer to the Bradford Corporation on the question of smoke. After three years, the Corporation concluded that mechanical stokers were very serviceable in reducing smoke.

Mr. Charles Erith said the first things that had struck him in the paper were the complete absence of reference to heat balance, to the condition and age of the plants, or to the general conditions of upkeep. He happened to have seen Mr. Brownlie's full report on one plant—tested at the end of the war period, after six years' use, no attempt being made to put it in order—and he had observed the remarkable fact that on the long check test of four boilers, covering 169 hours, with ordinary fuel, the results were considerably better than in the case of the eight-hour test quoted, made with a fuel not used before or since, and having very small efficiency. Mr. Brownlie had omitted an important factor, namely, the object of the tests. Apparently the author had some method of bringing boiler practice up to date, but had not given any example of the result of such re-organisation.

Of the 80 tests, covering 299 boilers, 5 covered 70 Lancashire boilers, of comparatively low pressure, all used in explosive works—war-time plants. The remaining 75 tests covered 229 only, in miscellaneous industries. It might be admitted that in the case of the five tests with 70 boilers, very little steam was used for power (roughtly, one-tenth, the rest being used for process work). It would have been interesting if Mr. Brownlie had been able to contrast American results in the case of similar explosive plants. Mr. Erith instanced the old Hickory plant, having 68 boilers, each capable of evaporating 45,000 lb. hourly, easily equal to six "Lancashire" boilers per unit.

Mr. Brownlie had attacked the national electrification scheme, and had spoken of stupendous expenditure, but he should be aware that capital cost was greatly reduced per kilowatt with the modern large unit plant. The author should also know that it was foolish to speak of reorganising small internally fired boilers, only suited for relatively small pressures and small superheat, many of them placed in positions where no proper condensing facilities were available. It was, moreover, absurd to contrast such plant with that of a centralised modern station having large units, surface condensers, turbines, water-tube boilers, and every facility for eliminating manual labour throughout the whole process.

The speaker would submit the following figure showing what was practicable in modern large-unit mechanically fired boiler tests. The test was of a single boiler and of 24-hours' duration. The boiler evaporated 82,995 lbs. of water hourly. There was no superheater or economiser, and the plant was strictly comparable to the class of boiler considered in the paper. The figures referred to were:—

Heat Losses.

	Per cent
In dry gas...	10·15
,, CO	0·04
,, evaporating moisture in coal ...	0·37
,, heating moisture in air	0·11
,, heat carried away by steam formed by burning hydrogen	3·66
By radiation of combustible in ash ...	7·56
Total heat loss	21·89

With exit gases at 467 deg. and boiler efficiency 78·11 per cent.

Continuing, Mr. Erith said that splendid as were these results, from the thermal point of view, in a boiler raising saturated steam at 116 lbs. pressure, they would be merely a ludicrous proposition for a modern power plant, with a steam pressure of 250 lb. to 300 lb., with considerable superheat, and with proper condensing conditions. The best reorganisation possible with a Lancashire boiler plant at 100 lb. pressure, slight superheat and non-condensing engine, was bound to be three, four or five times, or even more expensive in coal. No real attack on the coal saving problem could be made by generating power on a very small scale, necessarily under uneconomical conditions; the remedy was the wholesale scrapping of the small power plant, excluding cases where steam was required for process work.

Returning to the question of the tests, he would take the case of Job 23 (Table 14 of the paper) with 13 boilers, the gases left the economiser at 649 deg. Fahr. Again, in Job 24, with 10 Lancashire boilers the gases left the economiser at 612 deg. Fahr., while the corresponding figure for Job 11 (16 boilers) was 318 deg. Fahr. How was the extraordinary difference to be explained—the gases leaving the economisers at double the correct temperature? The discrepancy was attributed to the defects of mechanical stokers. With regard to steam jets there was no excuse for the figures being put in as characteristic of stokers, when the steam jets were taking ten times the steam they should normally take. If there were anything in a plant that was out of order, the defect should be put right before the tests were recorded.

Mr. Erith also directed attention to the ill effect on stokers of driving them by steam; in big modern plants stokers should be electrically driven, and not subjected to the modern high-pressure superheated steam. Steam drive could be highly economical, however, provided that the latent heat of the steam was recovered, either by condensing by contact with the feed water or in process work. In the test of paper mill plant referred to by the speaker, all the latent heat in the auxiliary exhaust steam was recovered by the use of the soda recovery plant, a fact entirely ignored in the test figures. For comparison with the large unit which he had mentioned, he would give the figures for Job 3 of Table 14 of the paper, a plant comprising the boilers at a pressure of 102 lb. with 40 deg. superheat. This installation burnt just under four tons of coal, while the evaporation was 69,600 lb. of steam per hour. If the plant was reorganised, as Mr. Brownlie would suggest by taking out the mechanical stokers and doing other things of that kind, there would be at least a 10-men shift.

Mr. David Rushworth thought Mr. Brownlie had overlooked one adjunct affecting the life of the boiler, *i.e.*, the fuel economiser. From long experience in the economiser business, he had found that mechanical stokers had such an effect on the tubes of an economiser as to reduce their period of life by one-half. Speaking of the coking and sprinkling type of mechanical stokers, using steam jets, the gases were condensed on the exterior of the tube at the lower ends, sulphurous or sulphuric acid being formed, with resultant eating away of the hard skin of the cast-iron tube. Perhaps the author would state his experience in this respect.

Mr. Alfred W. Bennis, the next speaker, said Mr. Brownlie had reflected upon the opinion of the Coal Control Department; that opinion was, however correct; mechanical stoking did save labour in the stokehole. One of the largest Government factories ran a range of 32 Lancashire boilers entirely with girl labour during the war, the girls being quite of the ordinary type. The record showed that this plant was the most economical in consumption of coal of any plant under the department's control.

The low grade fuel which Mr. Brownlie could not burn with his type of hand-fired forced draught furnace could be dealt with by the use of mechanical stokers or with self-cleaning furnaces. Many collieries were burning such fuel with 30 per cent. or 40 per cent. of ash, and doing satisfactorily. True, the output of the boilers was somewhat reduced, a natural consequence of using as fuel an absolute waste product. During the war, many people had to adopt mechanical stoking as an aid to steam production, when ordinary hand-firing would not maintain the supply. The authors' tests were mostly conducted during or immediately after the war when every factory was disorganised, when the real firemen had left and unskilled labour had taken their places, when the brickwork was bad and there were leaks all over the placé.

He took exception to the author's quotation of an efficiency figure of 81·1 per cent. on "Lancashire" boilers only, given by a mechanical stoker firm. His firm had published such a result, but had not stated that it was on boilers only; the figure was quoted for boiler, economiser and superheater, and it was stated then that every condition relating to the plant was as good as it could be. The figure was obtained from a test of eight "Lancashire" boilers, at the Formby Power House of the Lancashire & Yorkshire Railway, with weighed water and coal and about 30 observers; his firm had only to run the stokers and copy the figures obtained. These figures had been maintained and even slightly exceeded upon occasion, during a period of about twelve years.

Mr. Bennis then submitted a table of 26 tests, including a test of 164 hours duration, giving an average efficiency of 73·7 per cent., and an hourly evaporation of 11,241 lbs.

Range of Efficiency.	Number of Tests.	Percentage.	Mr. Brownlie's Table 3.
Per cent.			Per cent
Over 80	1	3·8	1·25
75-80	9	34·6	2·5
70-75	10	38·6	2·5
65-70	6	23·0	21·25

The CO_2 results given in table 4 did not, the speaker said, tally with Mr. Brownlie's conclusions. The latter had admitted that the CO_2 was better in mechanically-fired boilers, but stated that the results were worse. Something must be wrong with the figures in that table.

He thought, with regard to steam produced the figures of the 26 tests quoted would prove his point. Of course, in boiler plants it was not the aim to make all the steam possible, but what the factory actually required at the time. Therefore, an average of 600 gallons an hour might mean that between times the factory was only taking 400 gallons, while at another time it might take 1,000 gallons or more. On the question of the flexibility of stokers, Mr. Brownlie made the mistake of lumping together all classes of mechanical stokers. Obviously some stokers were good for moderate and steady loads; others for heavy and intermittent loads.

Mr. W. Reavell said that the plants covered by the authors' tests could scarcely be regarded as typical British plants; they were principally concerned with woollen dye and similiar industries in a certain part of the centre of England. Mr. Brownlie had made the deduction that, generally speaking, if first cost were taken and allowance made for interest, &c., stokers were of no advantage.

With regard to the quantity of steam used in connection with jets, it was surprising what a large percentage of the steam generated appeared to be used in the jets. A number of years' experience had impressed him with the fact that the amount of waste through leakages and small holes was great; and more steam passed through small jets than might be supposed. Judging from descriptions of jets he did not consider that much scientific engineering had been bestowed upon their form, &c.; the holes perforated in the ½-in. and 1-in. pipes were

not designed to give the best results from the steam blown through. It appeared to the speaker that the steam could be so used in some form of nozzle as to induce a flow of air, resulting in greater efficiency in the consumption of the steam.

Probably the average size of the plants dealt with by Mr. Brownlie was not great, but the author had apparently overlooked the fact that the mechanical system of firing did lessen the monotony of the firemen's work. The point was of value in these days, when employers would have to take the claims of labour into account. He could not conceive of a duller task than that of the fireman who day after day, week after week, and year after year, had nothing to do but to shovel coal into the furnace and clean the clinker out. From that point of view alone he regarded mechanical firing of boilers as a great advantage.

The speaker ventured to think that the statement in the paper to the effect that Lancashire boilers far exceeded other types in number was incorrect; certainly it would be still less correct if comparson were made of the horse-power or total evaporation of each type. Mr. Brownlie asserted that the "Lancashire" was essentially the standard boiler of the country, and had observed that the amount of coal consumed in Great Britain on "Lancashire" boilers was probably eight to ten times that on tubular boilers. Again, Mr. Reavell thought the author must be in error, nor could he accept the 58½ million tons of coal which Mr. Brownlie stated to be used for power produced by steam raising. It was commonly known that the power stations of the country used seven and a half million tons of coal per annum, and probably 90 per cent. of the boilers used were water-tube boilers. That alone was 11¼ per cent. of the whole, while it only took account of power station boilers, not regarding the boilers of this type in use in numerous industries.

Mr. David Wilson said that the abstract of his paper which Mr. Brownlie had read was sufficiently revised to soften the blow struck by the original. From this paper, anyone not fully conversant with modern power-plant might reach the conclusion that mechanical firing was a mistake, both for narrow-flued and water-tube boilers. It was, however, known that the demand for increased efficiency, output and labour-saving put hand-firing out of court for installations of any magnitude. Possibly Mr. Brownlie's investigations were confined to installations of small size, in which the type of furnace to be adopted must necessarily depend upon the class of coal to be used. If, however, high-grade, volatile coal were available mechanical firing effected no great saving; if the installation was a small one there would probably be very little labour-saving.

The people responsible for electric power supply had given more thought to the scientific combustion of fuel than any other body of steam users, and it was notable that while the water-tube boiler predominated in power stations, there were still 865 cylindrical boilers in use in such stations, and of these 566 were mechanically-fired and 299 hand-fired—or 66 per cent. mechanically-fired. Did the author suggest that the engineers responsible for the installation of these mechanical stokers in electric power stations were entirely wrong? The speaker then presented the following percentages of mechanically-fired boilers in use in various industries:—

	Per cent.
Woollen industry	42
Cotton industry	33

As regards locality, in the Yorkshire district of these industries 73 per cent. were mechanically fired, and in the Lancashire district, 31 per cent. Those figures spoke for themselves. With regard to the author's opinion that the Lancashire boiler was the standard unit, he might mention that there was no correct census of boilers in this country. The Coal Control Department failed in their endeavour to get a census, but from the information forthcoming, so far as it went, he could say that the total number of boilers (omitting those of collieries and gas works, of which data were not yet obtained) for steam-raising purposes was 76,000 of all types. Of that number 42,000 (or 55 per cent.) were of the cylindrical type, whereas Mr. Brownlie gave the figure of 92 per cent. for the cylindrical or Lancashire type. The boilers actually specified in the return as "Lancashire" only amounted to 29,000 (38 per cent.). In the case of water-tube boilers installed in industries in this country it was of little value to take the number of units installed; the only plan was to get relative figures of horse-power. When it was remembered that the cylindrical boiler was limited to small powers, whereas the water tube boiler was built up to as high a figure as 100,000 lb. per hour, he felt that if the relative figures for the two classes of boiler were computed in horse-power the result would astound Mr. Brownlie.

Mr. Brownlie had criticised the coal control remarking that he could not understand the Coal Control Department recommending mechanical stokers. The speaker, however, was unaware that the Department had made any hard and fast recommendation to instal mechanical stokers. As a matter of fact, when the economy campaign was started, instructions were given to inspecting engineers throughout the country that they must confine themselves to suggestions for economy, without introducing additional plant or advising structural alterations. He thought that the author's criticisms must refer to an address which he (the speaker) had delivered in Glasgow, in which he had predicted that eventually hand-firing would disappear. He still adhered to that view. The users of mechanical stokers were of the greatest assistance to the Coal Control Department during the period of serious trouble, in helping to burn peat, refuse, &c. One of the largest and most scientifically operated collieries in South Wales was equipping an entire plant with mechanical stokers after the fullest investigation.

Mr. Spyers, referring to the remarks in the paper on efficiency said, for the purposes of good comparison it was necessary, in all cases, to eliminate the effect of superheaters and economisers, which confused the issue. He would be surprised if Lancashire boiler makers would accept, without comment, the figure of 53 per cent. for the average net working efficiency for boilers only; the Lancashire boiler might be considered "prehistoric" in construction, but was not so bad as this figure would suggest. The speaker was inclined to agree that, with good firemen, the efficiency obtained with hand firing should be as good as with mechanical stoking. That would be perfectly true, provided the men were skilful and well disciplined; and the efficiency could probably be maintained over a fairly reasonable period. For long and continuous working of boilers in actual commercial practice, however, he had no hesitation in saying that the mechanical stoker was far better than the man. Mr. Brownlie was correct in saying that the mechanical stoker did not save labour. That was true because there was just as much labour involved in lifting the coal into a hopper as in lifting coal from the floor into a fire door; perhaps more. The gain with the mechanical stoker was the manner in which it lent itself to methods of coal handling.

Mr. W. H. Patchell strongly dissented from Mr. Brownlie's opinion that the mechanical stoker was of no use. Mr. Brownlie, dealing with his subject from the chemist's point of view, had been on the watch for CO_2, whereas those behind the shovel and the coal heap knew that the CO_2 was not everything. He regarded the condensation on economiser tubes as a matter rather for the engineer than for the chemist, because it was connected with the practical working of the boilers. It was not good practice to put cold water into economiser tubes, as condensation was, in that case, inevitable; if the feed were not hot there would be a sensible amount of corrosion on the outside of the tubes. Moreover, there was moisture in the coal, quite apart from the moisture going up the chimney from steam jets. With regard to steam jets, firms who had sold steam jets to the speaker had started with the statement that the steam consumption was about 2 per cent.; he had, however, found, from measurements, that the figure was nearer 15 per cent.

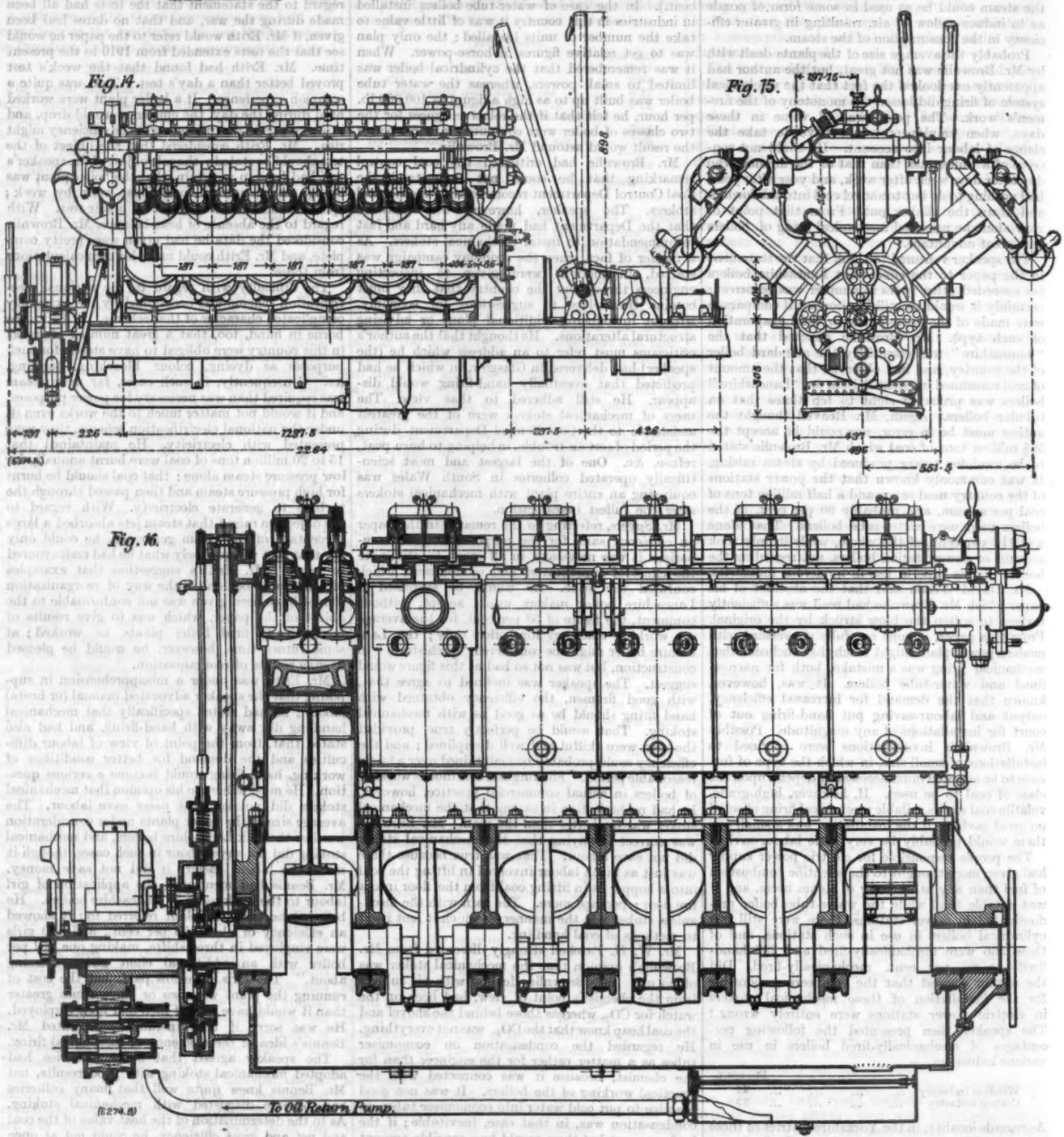
Mr. D. Brownlie then replied to the discussion, dealing very briefly with certain points only, the hour being late. He had not advocated hand-firing for Lancashire boilers, and had, in his paper, discussed the advantages and drawbacks of both methods of firing; he had merely stated that mechanical firing presented difficulty, and that its advocates had exaggerated its advantages. With regard to the statement that the tests had all been made during the war, and that no dates had been given, if Mr. Erith would refer to the paper he would see that the tests extended from 1910 to the present time. Mr. Erith had found that the week's test proved better than a day's test. That was quite a common experience. If a boiler plant were worked hard during the day, the efficiency would drop, and if worked again during the night the efficiency might rise. Mr. Erith considered that the object of the test should be stated; the sole object of the speaker's test had been to ascertain what the boiler plant was doing, under normal conditions, week by week; special conditions would not be a fair test. With regard to the absence of heat balance, Mr. Brownlie considered the data he had given were pretty complete, and Mr. Erith could make his own calculations from these.

The difficulty with regard to the national electrification scheme was occasioned by the extremely complicated character of that scheme. It had to be borne in mind, too, that a great number of works in this country were obliged to have steam, for such purposes as dyeing, colour bleaching, tanning, &c. Consequently, in such cases, far more steam was required than was necessary for power purposes, and it would not matter much to the works even if, under the national electrification scheme, they were presented with electricity. He maintained that 15 to 20 million tons of coal were burnt annually for low pressure steam alone; that coal should be burnt for high pressure steam and then passed through the turbine to generate electricity. With regard to the objection raised that steam jets absorbed a large percentage of the steam generated, he could only say that that was precisely what he had endeavoured to prove. Mr. Erith's suggestion that examples of what could be done in the way of reorganisation should have been given was not conformable to the object of the paper, which was to give results of mechanically fired boiler plants as worked; at some future time, however, he would be pleased to give results of reorganisation.

Mr. Erith was under a misapprehension in supposing that the speaker advocated manual (or brute) labour; he had stated specifically that mechanical handling did away with hand-firing, and had also stated that, from the point of view of labour difficulties and the demand for better conditions of working, hand-firing would become a serious question. He must adhere to his opinion that mechanical stokers did not in most cases save labour. The average size of the boiler plants under consideration was less than six Lancashire boilers, and mechanical stoking did not save labour in such cases, though it made the labour easier; it did not save money. Mr. Bennis had mentioned the application of girl labour to the working of 32 Lancashire boilers. He believed he knew the plant referred to; it showed an efficiency of about 55 per cent., and 120 girls were employed in three shifts, making one girl per boiler with an additional eight girls "messing about." The girls were low paid, but the cost of running the plant was two or three times greater than it would have been if men had been employed. He was sorry if that instance represented Mr. Bennis's idea of the efficiency of mechanical firing.

The speaker agreed that some collieries had adopted mechanical stoking with good results, but Mr. Bennis knew quite well that many collieries had become disgusted with mechanical stoking. As to the determination of the heat value of the coal and net and gross efficiency, he could not at once answer the questions raised, as the matter was complicated. It was best to base a boiler test on the gross efficiency as determined, and subtract the small number of British Thermal Units lost by the escape of steam in the flue gases. It had never been really settled what was the best way, but he believed that his method was favourable to the mechanical stoker. Mr. Bennis had quoted an efficiency of 80 per cent., a figure which the speaker did not dispute; in fact, one of his tables showed such a figure. He still adhered to his statement that not 5 per cent. of the boilers in this country were supplied with water meters, and that not 2 per cent. of the boilers were run on scientific lines. He would

EXHIBITS AT THE MOTOR-BOAT SHOW AT OLYMPIA.



FIGS. 14 TO 16. 18-CYLINDER 450-B.H.P. ENGINE; THE GREEN ENGINE COMPANY, LIMITED, TWICKENHAM.

point out to Mr. Reavell that the plants tested were not confined to the centre of England, but were distributed all over the British Isles—in the woollen industry in the west, and in England and Scotland (as far north as Aberdeen).

The President then closed the proceedings announcing that the next ordinary general meeting would take place on Friday, April 23.

"THE VENTILATOR."—This is the title of an illustrated magazine which is issued by members of the staff of Messrs. Edward Wood & Co., Limited, Ocean Iron Works, Manchester. It appeals to all the firm's employees.

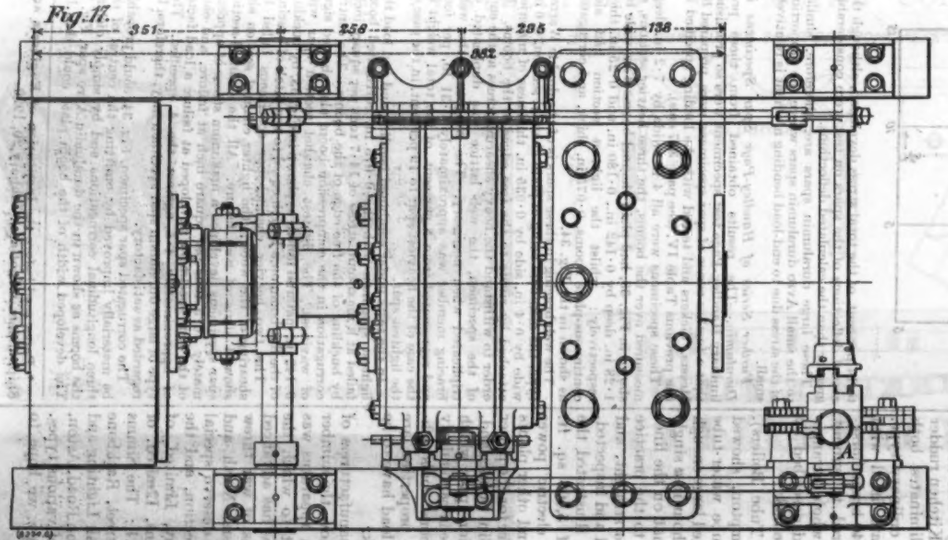
THE MOTOR BOAT SHOW AT OLYMPIA.

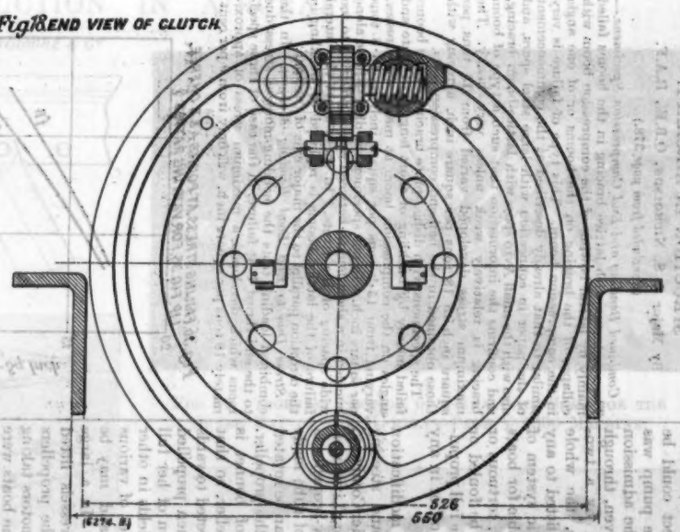
(*Concluded from page* 375.)

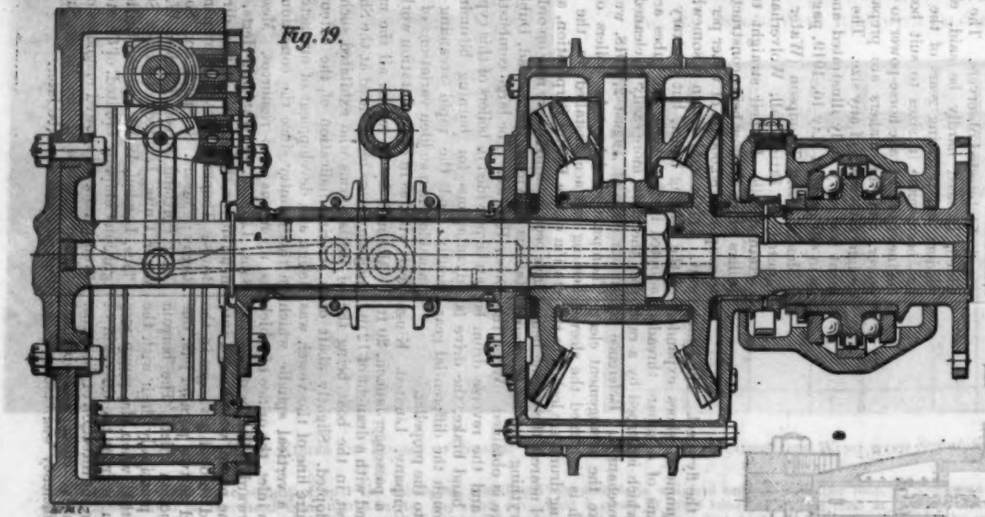
The Motor Boat Exhibition at Olympia closed its doors on March 20, after what was apparently a successful week's run. It is difficult to estimate the amount of business transacted during the period, but the effect of such exhibitions in educating the public to the state of the art, and in bringing home to possible purchasers the nature of the wares which await their orders, is perhaps more useful than the opportunities they offer for immediate sales. However this may be the Exhibition was creditable, both to the industry generally and to the numerous firms who had gone to considerable expense in preparing and transporting articles of an unusually large and heavy nature to the site.

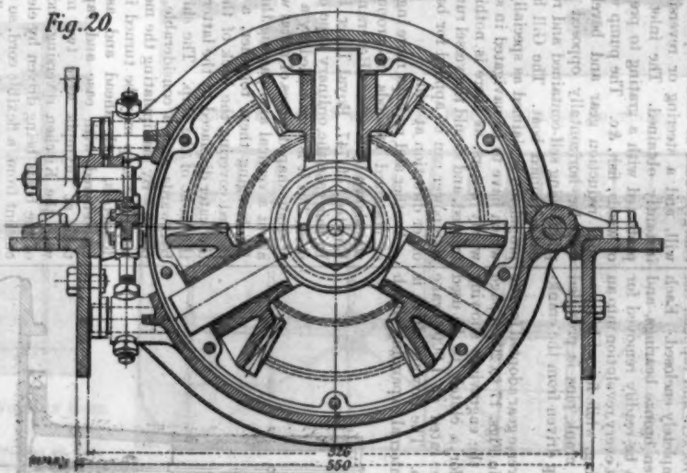
Continuing our description of the more interesting exhibits, we may refer to the stand of the Green Engine Company, Limited, of Edwin Road, Twickenham. This firm who have for many years specialised in the design of light high-powered internal combustion engines for aeronautical and marine purposes, showed several of their models, the most striking, perhaps, being an 18-cylinder engine rated at 450 brake horse-power. This engine follows

EXHIBITS AT THE MOTOR-BOAT SHOW AT OLYMPIA.









FIGS. 17 TO 20. 1,000-B.H.P. CLUTCH AND REVERSING GEAR; THE GREEN ENGINE COMPANY, LIMITED, TWICKENHAM.

largely on the lines which have proved so successful in the 12-cylinder 300 brake horse-power engines supplied in considerable numbers for the propulsion of H.M. Coastal Motor Boats during the war, and of which an example was also to be seen at the Exhibition. The 450 brake horse-power engine, however, is of the "Broad Arrow" type, its 18 cylinders being arranged in three rows of six, three cylinders driving each of the cranks of the six-throw crankshaft. The general arrangement of the cylinders will be clear from Figs. 14 and 15 on the opposite page, while Fig. 16 on the same page is a section reproduced on a larger scale in order to show the mechanical details more clearly. The cylinders are 142 mm. bore by 178 mm. stroke, and the engine delivers its rated horse-power at 1,250 r.p.m.

The cylinders are all cast singly, and are machined externally so as to reduce weight to a minimum, the water jackets, made of sheet copper, being fitted afterwards. The valves are placed in the cylinder heads, so that there is an entire absence of pockets in the combustion space. The valve cages are detachable and interchangeable, the lower end of each cage making a gas-tight joint upon a conical seating machined in the cylinder head. As the latter is somewhat larger in diameter than the bore of the cylinder it is impossible for a valve to drop into the cylinder and cause damage in the event of the valve stem breaking. Inlet and exhaust valves are identical in design and in dimensions, so that all valves are interchangeable and the number of spares which have to be carried is correspondingly reduced.

An overhead camshaft drives the valves for each line of cylinders through small rockers and tappets, the whole of the gear being completely enclosed. Each camshaft is carried on seven bronze bearings, and the casing of the shaft can be readily removed for inspection. The cams dip at every revolution into an oil bath formed in the casing, while forced lubrication of main bearings and crank pins is provided for by means of an oil pump driven from the crank-shaft.

The type of clutch and reverse gear adopted for the Green engine is illustrated in Figs. 17 to 20 on page 407, and Fig. 21 annexed, the engravings showing the proportions adopted for a clutch to be used with a 24-cylinder engine rated at 1,000 brake horse-power at 1,250 r.p.m. The forward drive is obtained by means of an internal expanding clutch

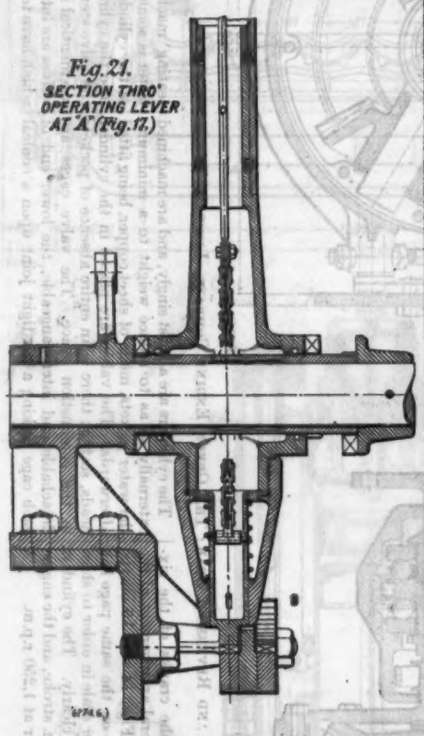


Fig. 21.
SECTION THRO' OPERATING LEVER AT 'A' (Fig. 17.)

working inside the rim of the flywheel. The clutch consists of a pair of gunmetal shoes expanded against the rim by means of a square threaded screw carrying a pinion which is turned by a rack actuated by the lever mechanism. Reference to Figs. 18 and 19 will make the arrangement clear. When the flywheel clutch is tightened the sleeve, and, therefore, the reversing drum, are locked to the shaft, and the bevel wheel nearest the engine being keyed to the shaft everything has to go round together, and a solid drive is obtained. When the flywheel clutch is loose and the reverse drum is held fast by its external band brake, the drive is then from the shaft, through the differential gear, which reverses it, and so to the propeller.

The Gill Propeller Company, Limited, Kings Lynn, Norfolk, exhibited a passenger launch, 20 ft. long by 5 ft. 6 in. beam, and with a draught of 12 in., the chief point of interest in the boat being the method of propulsion adopted. Slightly abaft of midships, and on the centre line of the vessel, was a centrifugal pump with a vertical spindle which drew in water through an inlet, the orifice of which was turned slightly forward. The water, after leaving the impeller of the pump, was divided into two streams which flowed through passages in the pump-casing and escaped as two parallel jets, one on either side of the suction inlet. The bottom of the pump-casing was practically flush with the bottom of the boat, so that when the pump was started water was drawn in from the direction of the bows and forced out in the direction of the stern. By this means a propulsive effect was obtained for which a very high efficiency was claimed. As the pump-casing was rotatable the inlet and discharges could be made to point in any direction at will, and a steering or reversing effect could be instantly obtained. The inlet to the pump was protected with a grating to prevent the admission of weeds, fish, &c. The pump was driven, through spur reduction gear and bevel gear, by a two-cylinder horizontally opposed engine, the whole plant being self-contained and readily fitted to any flat-bottomed boat. The Gill hydraulic system of propulsion is claimed as specially suitable for boats which have to be navigated in shallow, tortuous or weedy waters, as there is nothing to be fouled or injured, and should the vessel run ashore full propulsive power can be applied for backing off or in any other direction at will.

Another and perhaps more ingenious modification of standard methods of propulsion and steering was shown by Kitchens Reversing Rudder Company, Limited, of 747, Royal Liver Building, Liverpool. In this case the ordinary type of screw-propeller is used, but it is surrounded by a kind of tube made of scoop-shaped pieces of metal which can be rotated about a vertical axis passing through the propeller. By bringing them together, a kind of bonnet is formed covering the back of the propeller, so that the water displaced by the latter is directed towards the front of the ship. The ship is then propelled backwards with a considerable fraction of her full power. By manipulating the metal shields in other ways the ship may be turned in circles of various diameters, both ahead and astern, and may be manœuvred with ease and rapidity. In a large tank at Olympia were two model vessels fitted with the Kitchen reversing rudder, the propellers of the boats being driven by electric motors taking current from a flexible cord, so that the boats were free to manœuvre as desired. By suitable manipulation of the rudders, a proceeding which was almost instantaneous, the vessels were made to execute remarkable evolutions which always attracted a crowd of interested observers. The Kitchen rudder which, it need hardly be said, eliminates both rudders and reversing gears of the ordinary type, has been made in sizes to suit boats fitted with engines from 4 brake horse-power to 40 brake horse-power, and the makers are prepared to submit designs for vessels of any size. The whole arrangement was very fully illustrated and described by us in our issue of May 16, 1919, page 508.

Messrs. John Thompson (Water Tube Boilers), Limited, of Ettingshall, Wolverhampton, showed certain details of their straight tube water-tube boilers which are now being constructed large enough to evaporate 85,000 lb. of water per hour in a single unit. The general design is somewhat on the lines of the Stirling boiler, but contrary to the practice adopted in that type, the tubes are straight, and can, therefore, more easily be cleaned and inspected. In our issue of August 2, 1918, we illustrated the Thompson straight tube boilers of 5,400 sq. ft. heating surface installed in the electric power station of the Bristol Corporation, and other plants have been installed or are now on order for the power stations at Wigan, Hampstead, Dublin, Sunderland, Ocker Hill, &c. The large combustion space which can be provided in boilers of this type is particularly advantageous for burning bituminous coals efficiently, and the rapid steaming properties are valuable when sudden variations of load have to be dealt with, as in central station work.

Although by no means all the manufacturers of magnetos were represented at the Show, the number of British firms who exhibited such apparatus was a striking indication of the extent to which the design and development of magnetos has advanced in this country since the conditions of war threw us upon our own resources. Messrs. North and Sons, Limited, of Watford, Herts, deserve special mention for their work in this direction, and the British Thomson-Houston Company, Limited, of Rugby; Messrs. S. Smith and Sons, Limited, of Great Portland Street, London, W.1; The Simms Motor Units, Limited, of Grosse Street, Rathbone Place, London, W.1; and the British Lighting and Ignition Company Limited, of Cheston Road, Aston, Birmingham, all showed magnetos of various types.

Other exhibits at the Motor Show we hope to illustrate and describe later.

THE DEVELOPMENT OF METAL CONSTRUCTION IN AIRCRAFT.*

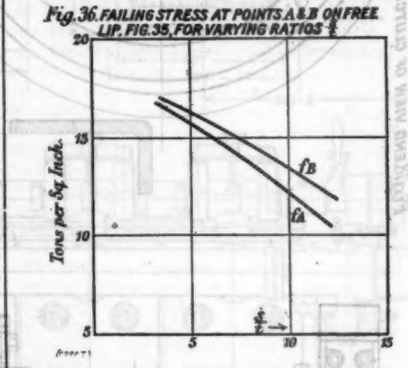
By Major J. S. NICHOLSON, O.B.E., R.A.F.

(*Concluded from page 378.*)

Combined Bending and End Compression Specimens.—The specimens with lattice bracing in the booms failed mainly by lateral bowing of the compression boom with collapse of the bracing on the booms or of one angle in the compression boom. This type of failure is very similar to that already described at the commencement of the paper in connection with large steel spars, and also with the small Avro spars with lattice-boom bracing, and confirms the information that such a type of boom bracing is relatively weak unless very heavy. The maximum stress developed varied from 13 tons per square inch to 18 tons per square inch, agreeing with those obtained in the ball-end compression tests.

The specimens with dished-plate bracing in the booms failed mainly by buckling of short lengths of plate and angles on the compression boom at maximum stresses, varying from 15·2 tons per square inch to 18·8 tons per square inch. In one specimen the dished-plate alone buckled in a short length between rivets, pointing to too wide spacing of the rivets. In these spars the lateral failure of the lattice booms is replaced by buckling in the direction parallel to the major axis of the spar.

Stress Due to End Load Bending Moment.—In the combined loading tests the bending-moment stress due to the end thrust P at failure, in the case of those specimens which developed a maximum stress of approximately 18 tons per square inch, was only from 9 per cent



to 14 per cent. of the total stress developed, although the actual deflections of the spars on test were considerably greater than the calculated deflections.

These large duralumin spars are, therefore, similar to the small Avro duralumin spars where the proportion of the stress due to end-load bending moment is relatively small.

Further Series of Handley-Page Spar Specimens in Duralumin.—The results obtained from these preliminary Handley-Page test specimens were so promising that a further series of spar specimens were prepared by Messrs. Vickers and tested with the loading specified in the previous Table IV. (see page 377 *ante*).

These specimens were all 4 in. wide by 7·2 in. deep, measured over the booms, the three heavier sections, as shown in Fig. 33, had plain channel booms 4 in. wide by 1·28 in. deep by 0·142 in., 0·180 in. and 0·25 in. thick respectively; whilst the lightest section had also continuous-plate booms, 0·075 in. thick, and corrugated as shown in the Fig. 34.

The web bracing in these spars is of the double Warren type, the members being of plain channel section, 0·6 in. wide by 0·4 in. side by 0·035 in. thickness of material, attached by rivets to the free edges of the booms. In order to withstand the heavy shearing forces at the ends of the specimen, the web lattice was duplicated or triplicated when necessary. The weight of the web-bracing member was approximately 0·31 lb. per foot and represented from 8 per cent. of the total weight in the case of the heaviest spar to 19 per cent. in the case of the lightest spar.

In the tests under combined bending and end load the lightest specimen with the 0·075 in. corrugated boom failed at a maximum stress of 14·7 tons per square inch, by buckling of the free edge of the booms. The central corrugation in the compression boom also showed signs of waviness. The lightest channel section spar with 0·142 in. material failed, as shown in Fig. 33, by buckling of the flat boom on a length equal to the pitch of bracing.

The two heavier channel-spar specimens failed by shearing of the webs; the lighter channel section also showed signs of web failure. All the channel-section spar specimens developed a maximum stress of approximately 16·5 tons per square inch at failure, and each of the four specimens developed at failure a load factor of approximately 4·5 against the 4 specified. This type of large duralumin spar specimen may, therefore, be regarded as satisfactory.

The corrugated spar specimen, Fig. 34, could probably be materially improved by omitting the central of the three longitudinal corrugations and by simply dishing the booms as shown in the duralumin Avro spar, Fig. 7. The developed width of the boom plate could thus be

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, January 20, 1920.

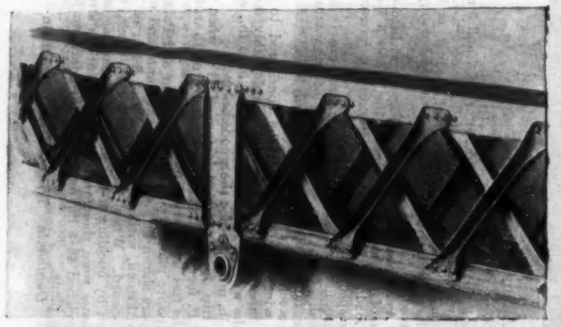
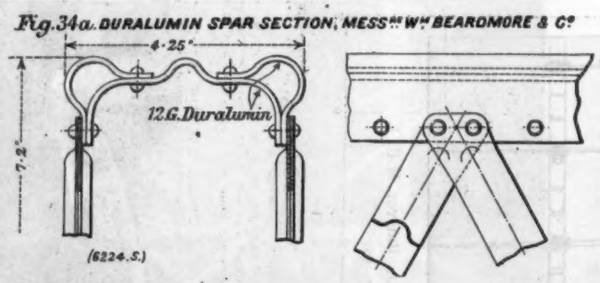


FIG. 33. HEAVIER DURALUMIN CHANNEL-SPAR SPECIMEN.



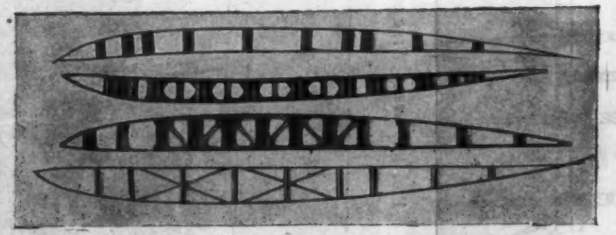


FIG. 37. STEEL WING RIBS WITH CHANNEL SHAPED BOOMS.

FIG. 34. LIGHTEST SECTION OF DURALUMIN SPAR FOR THE OUTER BAY OF THE HANDLEY-PAGE V 1500 MACHINE.

FIG. 35. STRESS IN FREE EDGES OF BOOMS OF SPARS.

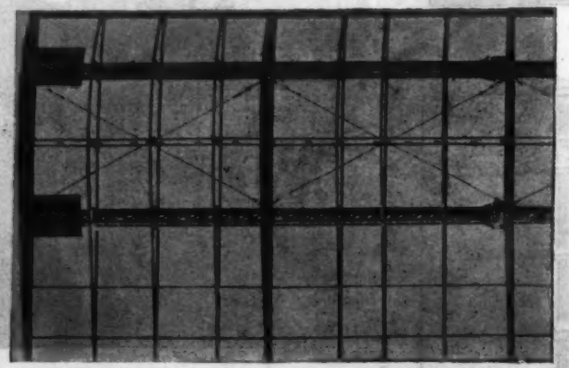


FIG. 39. AVRO COMPOSITE WING WITH STEEL SPARS & WOODEN RIBS.

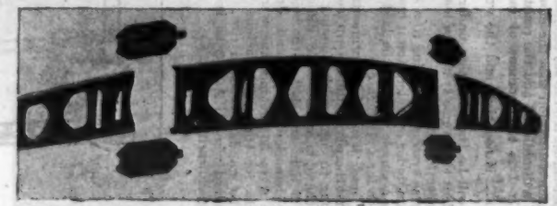


FIG. 38. PRESSED-STEEL WING RIBS, IN THREE PORTIONS.

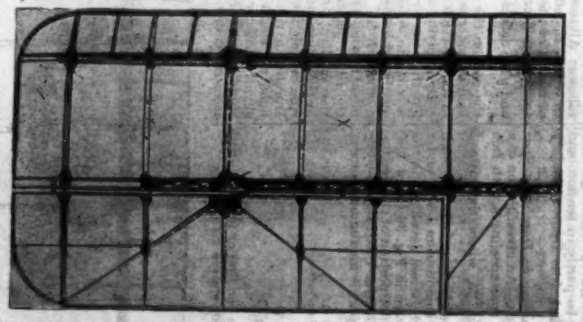


FIG. 40. EARLY TYPE OF ALL-STEEL AVRO WING WITH AILERON.

reduced, and for the same weight of spar the thickness of the plate could be increased from 0·075 in. to, say 0·090 in. The free lips of the booms would be materially strengthened by the thickening of the material.

The material in the central corrugation of this boom is not nearly so effective for withstanding end load as the side corrugations; it is supported in a "springy" manner along its two edges from the side corrugations, and will offer less resistance to transverse bowing under end load than would the side corrugations, which are supported on one edge at least by the web bracing.

An alternative method of stiffening up the central corrugation is by duplicating the boom at the outer corrugations, as shown in Fig. 34A in the duralumin spar constructed by Messrs. William Beardmore and Co., Dalmuir.

This duralumin spar specimen for the inner bay of the Handley-Page aeroplane weighed only 3·2 lb. per foot, and developed a stress of 20·8 tons per square inch at failure, with a load factor of 4. This high stress compares favourably with the 18 tons per square inch usually developed in duralumin spars, and indicated that the whole boom was very rigid.

The question of the number of corrugations in a wide compression boom or, in other words, the method of stiffening of a wide plate, is of great importance, and offers a wide field for experimental research. It appears probable that (*a*) the number of corrugations should be kept as small as possible, and (*b*) the depth of the corrugations should be such that the radius of gyration normal to the plate is large enough to prevent bowing of the stiffened boom on a length equal to the pitch of the web bracing.

Influence of Web Bracing in the Larger Duralumin Specimens.—With the web bracing shown the maximum fibre stress due to the bending moment produced by the end thrust varied from 7 per cent. to 17 per cent. of the total stress, 16·5 tons per square inch at failure in the case of the specimens with plain channel booms. In the case with the 17 per cent. component of the stress the central deflection of the specimen was 0·87 in., the deflection due to the transverse bending moment making up exactly one-third of that amount. Two-thirds of the actual deflection was, therefore, due to the bowing of the web bracing under shear forces and to the end thrust.

A stiffening of the web bracing, although probably advisable from a consideration of the shear forces alone would not materially affect the stress due to the end load bending moment. Any stiffening of the web bracing, however, would mean an increase in the weight of the bracing beyond the present 8 per cent. to 19 per cent. of the weight of the whole spar, and it is, therefore, problematical whether the increased weight of a spar would withstand a correspondingly equivalent loading.

Since these bracing members are not loaded axially the compression members will bow as a whole consider-

ably before complete failure occurs by buckling. The free lips of these members will be partly in tension, and are therefore to a great extent free from secondary failure.

Secondary Failure of Flat Surfaces in Duralumin Spar Specimens. Strength of Free Lips.—An investigation of a number of cases of duralumin spar specimens with free lips, of the type shown in Fig. 35, where the ratio $\frac{a}{t}$ varied from 5 to 12, and where the spar failed through buckling of the free lip of the compression boom under combined loading, shows that the stress developed in the free lips at failure varied as shown in Fig. 36 (page 408) at the two sides A and B of the flat portion of the free lip.

Main-Plane Spar Design: General Conclusions.—The essential requirement in these spars is maximum moment of resistance,

$$M = f\frac{I}{y} = f \times Z$$

Also

$$M = \frac{I\,E}{R},$$

whether the design is for simple bending or for combined bending with the end load or for simple struts.

The condition for failure may possibly be stated as follows: All sections under thrust tend to set themselves, to bow or to deflect, in such a direction that the moment of inertia of the section is diminished and the resistance to bowing decreased. If I is the moment of inertia and y the deflection, then $\frac{dI}{dy}$ is negative, and the weaker the section the greater will be the deflection under end load or under an equivalent transverse system of loading in the direction of the deflection.

By applying a transverse system of loading to a short length of the boom section under consideration it may be possible to determine in a simple manner the best of a number of forms of section for a given case.

Metal Ribs, Ailerons and Wings.—Experiments on metal ribs have proved that there is no difficulty in making the ribs sufficiently strong to support the loading. In the smaller machines there is considerable difficulty in producing metal ribs as light and stiff as the wooden ribs, which are usually remarkably rigid and strong. Duralumin ribs for the Avro 504 K machine were as light as, whilst steel ribs for the same machine were slightly heavier than, the standard wooden ribs. The simplicity of these standard wooden Avro ribs is seen from the composite wing shown in Fig. 39.

Fig. 43. The fuselage of this machine is built of hard-rolled aluminium sheets stiffened on the inside with other transversely corrugated sheets, the struts are of steel tubing.

Static Tests on Steel Wings and Ailerons.—Under static load the Bristol M.R.1 wing withstood a load factor of 6, when the front spar buckled downwards near to the inner end, causing collapse of the wing and failure of the rear spar also. In a rib test with the centre of pressure forward, failure occurred at a load factor of 8·2 by shearing in front of the front spar; when tested with the centre of pressure back, failure occurred at a load factor of 6·8 by tension in the diagonal members. The tests showed these wings to be of sufficient strength. Under static load test of the B.E.2D wings with centre of pressure forward, the wing withstood a load factor of 5·82 at failure, against the specified 5. Failure occurred in the compression boom of the front spar just inside the outer strut near to an additional strengthening plate. The ailerons and ribs were also of sufficient strength. The Avro steel wings shown in Fig. 41 were proof loaded to a load factor of 4·2 with the centre of pressure forward and to 3·7 with the centre of pressure back. On removal of the load in each case the spars, &c., returned to their original position. The deflection was normal, and there was no lateral bowing. Load factors of 7 and 5 respectively were required before failure occurred. The strength, as indicated by the proof loading, and from the behaviour of similar wings, was considered ample for flight tests.

The Avro steel wing shown in Fig. 40 withstood load factors of 8·7 and 7·94, against the 7 and 5 specified when loaded with the centre of pressure forward and back respectively. In the C.P. forward test an inner lift wire fitting failed, the wing structure being undamaged. In the C.P. back test the loading was stopped by the failure of the neighbouring composite wing; the all-steel wing was undamaged.

The wings may, therefore, be considered to be of ample strength. They are very considerably stronger than the wooden planes, and weighed 55·5 lb., against the 47 lb. minimum for the wooden planes.

The ribs developed load factors of 11·9 when tested with C.P. forward, and at a load factor of 15 with C.P. back the test was discontinued.

Composite planes by Messrs. Boulton and Paul, with steel spars shown in Fig. 13 (page 360 *ante*) and wooden ribs, withstood, without failure, a load factor of 7 with C.P. forward. When tested with C.P. back, failure occurred by buckling of the webs at a load factor of 6. The planes were, therefore, considerably above strength. They weighed 46·5 lb., against 47 lb. minimum for the wooden plane.

Avro Duralumin Wings.—The duralumin wings

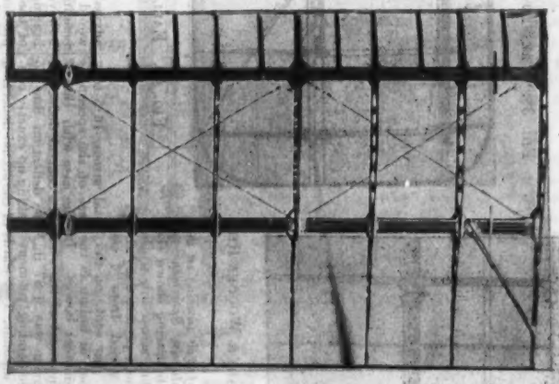


FIG. 41. ALL-STEEL AVRO WING WITH ROLLED SPARS AND PRESSED RIBS.

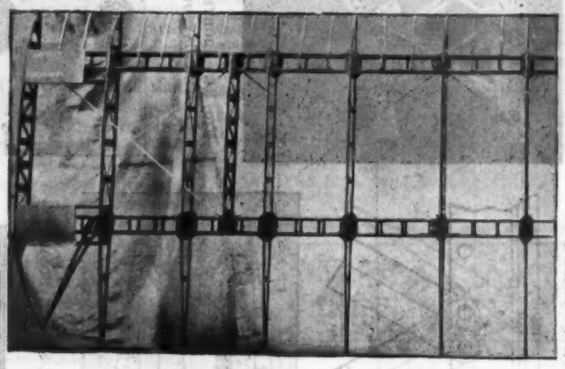


FIG. 43. STEEL WING FOR BRISTOL M.R. 1.

All the experiments on built-up specimens prove that it is very difficult to avoid unsupported surfaces at the junctions of the several parts, and that failure of the specimen usually commences at these surfaces or, in other words, the strength of the whole specimen is limited by the buckling strength of a partly supported, overhung portion of the spar specimen. The number of separate pieces in the section, and especially in the booms, should therefore be kept to a minimum.

Designs with the booms all in one piece are probably preferable to those with corner members (angles, &c.) braced together by lattice members or even by a single continuous corrugated plate.

A spar with booms formed from a single piece such as a longitudinally-corrugated plate may have a smaller moment of inertia I_{yy} about the vertical axis of the spar than one of equal weight per foot run with relatively heavy angles at the corners, and should have a greater tendency towards lateral failure, but this tendency is resisted by the rib connections between the front and rear spars of the wings. I understand that such a lateral failure of the two spars or of the wing as a whole is most unlikely.

In metal design of the complete wing it is necessary to incorporate a stiff leading edge, if the wing is to be transportable without elaborate packing. Strength alone of the leading edge is insufficient. Such a stiff leading edge in the wing greatly supports the front spar against lateral failure, and may with profit be considered as an additional main-plane spar, especially if the front main-plane spar is constructed of two narrow spars side by side for convenience in attaching the interplane strut and wiring fittings at the neutral axis of the spar. As already explained, this division of the main-plane spar may considerably weaken the spar in a lateral direction under the large end thrust.

In built-up spars of the larger sizes the attachment of the web and boom bracing calls for very special jig work or for highly-skilled workmen. This bracing, if redundant, and composed of short members made of high tensile material, is almost certain to be initially stressed, and under load the forces are not equally divided among the members (say between the two webs of the spar), and early failure is certain to occur. Any lattice-bracing member should probably be capable of withstanding thrust as well as pull.

Manner of Failure under Compressive Stresses.—One can probably predict the direction of failure of a single member, but when the member, such as a boom, is built up of several members riveted together it becomes a difficult matter to predict the direction of the failure, and hence to guard against it.

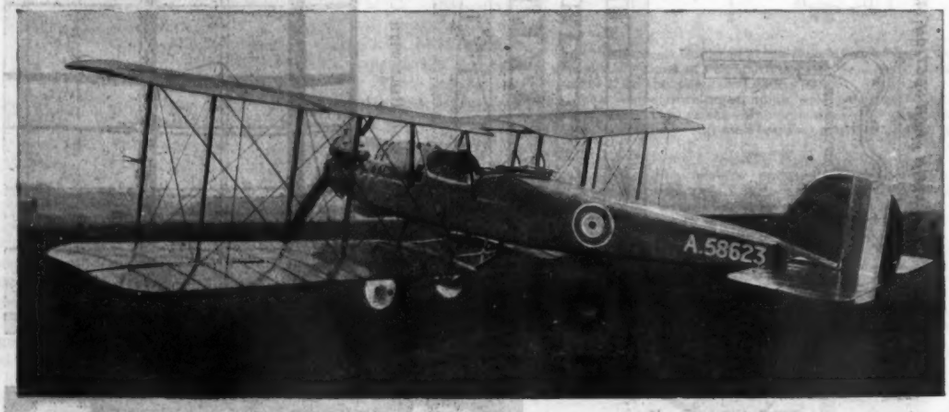


FIG. 42. ALL-METAL BRISTOL M.R. 1 AEROPLANE.

A number of types of steel ribs, by Messrs. The Steel Wing Company, built up of channel section with corrugated web pieces, are shown in Figs. 37 and 38. The lighter ribs shown in Fig. 37 were not very rigid; the channel section developed "kinks," giving a weak trailing section to the rib. The pressed-steel ribs, built up in three portions, are shown in Fig. 38. The portions of this rib butt closely up to the steel spars, and are attached to them by the saddle plates shown in the figure.

Steel wings designed and constructed by Messrs. The Steel Wing Company are shown in Figs. 39 to 41 and 43. A portion of an Avro composite wing with steel spars, as illustrated in Fig. 17a (page 360 *ante*), and standard wooden ribs, is shown in Fig. 39. An all-steel Avro wing aileron is shown in Fig. 40; whilst Fig. 41 shows a later construction of Avro wing with rolled steel spars, as illustrated in Fig. 17c, and with pressed-steel ribs.

One of the earliest types of all-metal wings constructed by Messrs. The Steel Wing Company was for the B.E.2D aeroplane. The construction was similar to that shown in Fig. 40. The main spars are of the type illustrated in Fig. 17a.

A view of the Bristol M.R.1 machine, probably the first all-metal aeroplane in this country, is given in Fig. 42. This biplane was constructed by Messrs. The British and Colonial Aeroplane Company, Bristol, the main planes being designed and built by Messrs. The Steel Wing Company. A view of the steel wing is given in

constructed by Messrs. Vickers and Co., for the Avro machine are shown in Figs. 44 to 46. The main spars have already been illustrated in Fig. 7. It will be seen that the compression ribs are similar to the main spars. The light form of the ribs, together with the robust tubular leading-edge should also be noted.

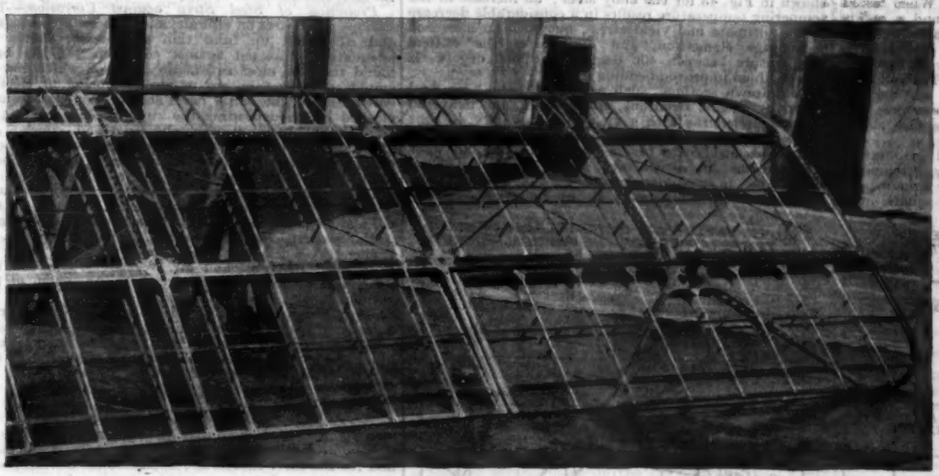


FIG. 44. DURALUMIN WING FOR AVRO 504 K.

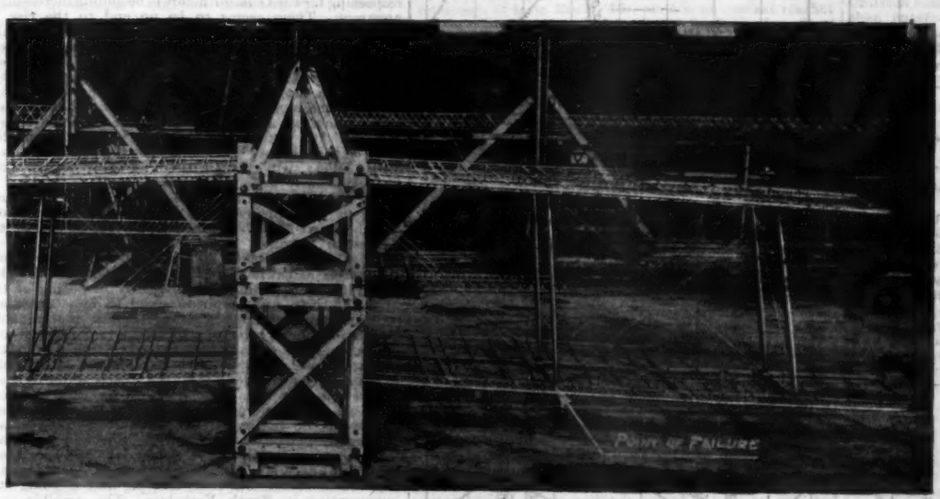


FIG. 45. SET OF DURALUMIN WINGS AFTER FAILURE IN STATIC TEST.

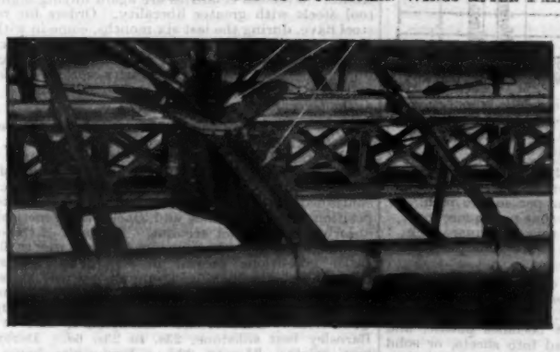


FIG. 46. STRUT FITTINGS WHERE FAILURE OCCURRED IN DURALUMIN WINGS.

The wings shown in Figs. 45 and 46 were tested at Barrow-in-Furness with C.P. forward, and failure occurred at a load factor of 10·7 by shearing of the rivets securing the gusset plate to the spar at the inner front strut fitting. The strut socket and gusset plate slid along the main spar until stopped by the bolts. On dismantling, it was found that the spar was undamaged. There was no visible lateral distortion of the spars or of the leading edge.

A large number of static tests were subsequently carried out at Farnborough on similar Avro duralumin wing construction. Very high load factors were consistently obtained, and failure never occurred in the spars. The tests were usually brought to a stop by failure of one of the standard fittings or of the drag bracing. When tested with all the flying and incidence wires in position, load factors of fully 11·2 and 9·8 were reached when tested with C.P. forward and with C.P. back respectively, and when tested with the incidence wiring, and also the wires from the lower plane to the skid removed, load factors of 7·8 and 6·5 respectively were reached when failure occurred at the fittings. When this load factor of 7·8 was reached the distortion of the planes was so great that loading could not be continued. There were several minor distortions in the drag struts, and in one case the riveting sheared on one side of a cover plate at a butt joint in the main spar, but after these large loads had been removed the main spars and the leading-edge invariably recovered.

The wings weighed 48 lb., a considerable proportion of this weight being required for the packing blocks due to the standard Avro type of fitting being employed.

An interesting example of a duralumin aileron for the Avro machine is shown in Fig. 47. The aileron is constructed on a special tube joint system by Messrs. M. L. Experimental Company, Dartford, and forms a very light and strong construction.

Flight Tests.—Numerous flight tests have been carried out with the steel B.E.2D and Avro main planes, constructed by Messrs. The Steel Wing Company, without the appearance of any signs of failure from the frequent landings and other severe flight tests to which they have been subjected. The planes have been stripped and carefully examined for failure of the riveting, internal bracing, &c. The only defects observed have been minor, such as the buckling of a number of ribs on the upper sides of the wings near to the trailing edge. A large number of flight tests have also been carried out with success with the Vickers duralumin Avro wings.

Flight tests on the Bristol M.R.1 aeroplane were also satisfactory. The machine finally made a bad landing, one of the lower wings crashing into a tree. A portion of the wing was badly crumpled, but not destroyed, the pilot being uninjured. It is probable that with an ordinary wooden machine the damage would have been much greater.

MATERIALS OF CONSTRUCTION FOR MAIN-PLANE SPARS, RIBS, &C.

Steel Strip.—The steel strip for the manufacture of wings for the smaller-sized machines is necessarily very thin, being usually from 0·012 in. to 0·022 in. if the weight of the steel structure is to be kept down to that of the standard wooden structure. For the larger types of aeroplanes the steel strip may probably be as thick as 0·036 in.

The minimum radius of curvature to which the high-tensile steel strip need be bent in the manufacture of the main-plane spars is about three times its own thickness, and hence all-steel strip, alloy or plain carbon, should be capable of bending to a radius of three times its thickness in cold rolling to the final form. In general, in the booms of steel spars which develop a maximum fibre stress of 50 tons to 60 tons per square inch or high, the usual radius of curvature in the strip ranges from 30 times to 10 times the thickness of the strip.

A consideration of the various spar designs which have been developed indicates the need for at least two qualities of steel strip giving yield stresses of (*a*) 40 tons per square inch and (*b*) 60 tons per square inch, the yield stress being specified because this cold-worked material has no definite elastic limit.

The yield stress itself is rather indefinite, and may be defined here broadly as that stress at which the permanent extension of the specimen under tensile test is visible. With high-tensile material developing from 60 tons per square inch to 80 tons per square inch the elastic extension is relatively large. For example, at 62·5 tons per square inch the elastic extension on a 4-in. specimen is approximately 0·02 in., and it is not possible to fix the yield stress without plotting a stress strain curve.

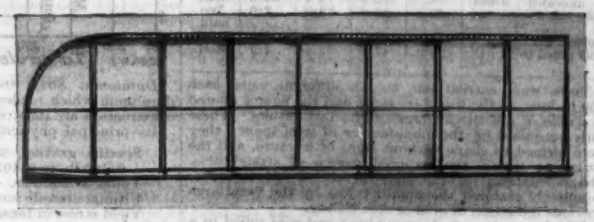


FIG. 47. DURALUMIN AILERON ON TUBE-JOINT SYSTEM.

The strip has been supplied either as alloy steel or as plain carbon steel, and both types are eminently suitable for the purpose, giving the required bend tests, and being capable of cold-rolling to the required form.

Alloy steel strip of tensile strength greater than 70 tons per square inch has been supplied by Messrs. Kayser Ellison and Co., Sheffield, in their K.E. 897 brand, and for those of lower tensile strengths their K.E. 169 brand is employed.

The composition of these steel strips is, on the average:

—	Carbon.	Chromium.	Nickel.	Vanadium.
K.E. 169	0·20	1·0	3·5	0·10
K.E. 897	0·35	1·25	3·5	0·10

The steel strip is cold rolled to the finished thickness.

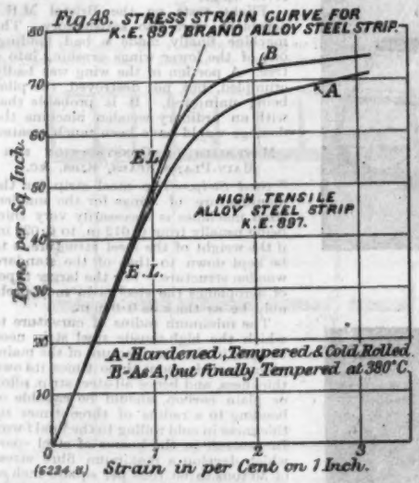
It is then heated and hardened by quenching in the oil in water from about 820 deg. C. The strip is then flattened by cold rolling, and is finally tempered for about 1 hour at a temperature of about 400 deg. C., and cooled in air.

This strip, when uncoiled and laid out straight, does not exceed in curvature ¼ in. in 10 ft. When tested against the grain the strip will bend round a radius three times its own thickness, through an angle of 180 deg.

A typical stress strain curve for K.E. 897 strip is shown in Fig. 48. The influence on the yield stress of tempering for 20 minutes is also shown. The influence of heat treatment, hardening in oil from 820 deg. C., and keeping for 1 hour at various temperatures and cooling in air, on the K.E. 169 brand, is also shown for 1½ in. diameter specimens in Fig. 49.

Very similar heat treatment curves will be obtained from the K.E. 897 brand, and the strip may be tempered down to give a yield stress of 40 tons per square inch, with an ultimate stress of 50 tons per square inch,

Fig. 48. STRESS STRAIN CURVE FOR K.E. 897 BRAND ALLOY STEEL STRIP.



and an elongation of 12 per cent. on 1 in. with excellent bending qualities.

Plain Carbon Steels.—A large amount of experimental work has been carried out by Messrs. A. Lee and Sons, Limited, Sheffield, on the production of plain carbon steel in qualities from 40 tons per square inch to 60 tons per square inch yield stress, with the result that the carbon steel strip has also been found to be suitable for the production of these main plane spars.

The following information regarding a low carbon steel strip with 0·30 carbon and 0·85 manganese will be interesting :—

TABLE V.

Condition.	Thickness. Inch.	Reduction of area Percentage.	Yield Stress. Tons per sq. in.	Ultimate Stress. Tons per sq. in.	Elongation Percentage on 1 in.	Bend Test. over Three Times its own Thickness.
Close annealed	0·064	—	15·3	18·4	39·5	Good.
Cold rolled to	0·024	62·5	39·0	29·0	2·6	Too hard.
Normalised	0·024	—	33·0	36·5	7·5	Good.
Cold rolled to	0·018	25·0	47·5	53·5	4·0	Good.

Tests were carried out on six different coils, each 450 ft. long, of the 0·018-in. strip, and the figures quoted in Table V are the average of the test results. These coils were used for the manufacture of steel spars ; they were formed to shape without signs of fracture, and the strip was within the required degree of straightness. The normalising of the strip at the 0·024 thickness completely restored the ductility lost by the very large previous reduction of area in cold rolling.

A higher carbon steel, normalised and cold rolled in a similar manner gave the following final test results :—

TABLE VI.

Condition of Strip.	Thickness. Inch.	Yield Stress. Tons per sq. in.	Ultimate Stress. Tons per sq. in.	Elongation on 1 in. Percentage.	Bend Test. Over Three Times its own Thickness.
Cold rolled to..	0·016	60·6	62·2	6·0	Good.
Cold rolled to..	0·018	62·0	64·0	12·0	Good.
Cold rolled to..	0·020	61·5	65·2	10·0	Good.

Coils giving the tests in Table VI were also manufactured into main-plane spars without showing any signs of failure.

The effect of tempering at 350 deg. C. this cold-worked plain carbon steel strip is similar to that shown in Fig. 48 for the alloy steel strip, and would probably result in an increase in the ultimate stress, together with a 5 tons to 10 tons per square inch increase in the yield stress.

The influence of tempering on the oil-quenched plain carbon steel strip is different to that on the cold-worked plain carbon steel strip, and is rather similar to that shown in Fig. 48 for the alloy steel ; an increase in the tempering temperature results in a considerable decrease in the ultimate and yield stress, but with an increased percentage elongation, and also, after the critical temperature between 400 deg. C. and 500 deg. C. is passed, in an improved bending test.

Cold-drawn sections, such as angles, have been produced by Messrs. Bruntons, Musselburgh, and delivered in straight lengths with a yield stress of fully 40 tons per square inch. Such sections, when built up with continuous steel strip bracing in the booms and webs should result in satisfactory spars. Hot-rolled alloy steel angles, in sizes down to ½ in. by ½ in. by ⅛ in., have also been supplied by Messrs. Brown Bailey, Sheffield.

Fig. 49. INFLUENCE OF TEMPERING AT VARIOUS TEMPERATURES ON THE PHYSICAL PROPERTIES OF K.E. 169 ALLOY STEEL.

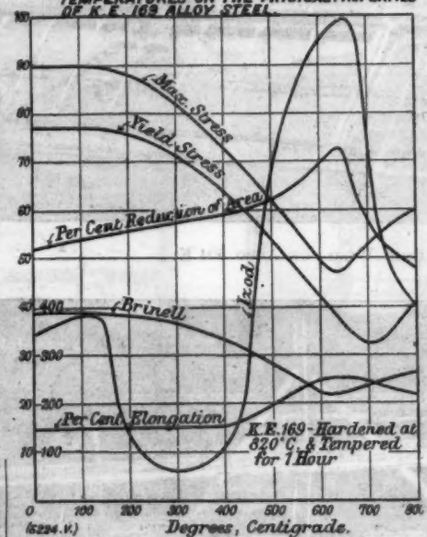
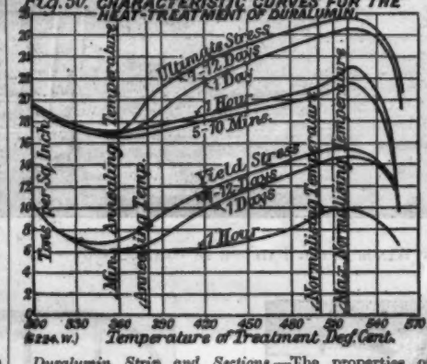


Fig. 50. CHARACTERISTIC CURVES FOR THE HEAT-TREATMENT OF DURALUMIN.



Duralumin Strip and Sections.—The properties of duralumin which render it eminently suited for aircraft construction are its strength and low specific gravity.

Its principal physical properties are :—

Specific gravity, 2·80 to 2·85, corresponding to 0·100 lb. to 0·102 lb. per cubic inch.
Young's modulus, 4,800 tons per square inch.
Ultimate tensile strength, 26 tons per square inch.
Yield stress in tension, 14·5 tons per square inch.
Compressive stress, 18 tons to 20 tons per square inch.

These physical properties are dependent on the heat treatment. It is annealed by heating to a temperature between 360 deg. and 380 deg. C., and quenching out in water. Under this treatment it becomes plastic, and may be forged or stamped, rolled into sheets, or solid drawn into sections or tubes. The tensile strength does not exceed 16 tons to 17 tons per square inch, with a yield stress of 6 tons to 7 tons per square inch.

The duralumin is normalised by heating to 500 deg. C. and quenching in water, the physical properties for 1 hour after the treatment being ultimate stress 22 tons per square inch with a yield stress of 9 tons per square inch, these stresses gradually increasing during the next 10 days to an ultimate stress of 27 tons per square inch with a yield stress of 15 tons per square inch. A correct heat treatment, preferably in a bath of potassium and sodium nitrates, is essential if the properties of the metal are to be developed.

An interesting series of characteristic curves showing the influence of the temperature of treatment on the final properties has been determined by Messrs. Vickers, and is shown in Fig. 50.

If it is impossible or inconvenient to heat-treat after the construction of the parts, the material should be normalised before the final operation and advantage taken of its relatively soft condition immediately after the heat treatment for the required mechanical operation.

Protection of Steel Strip against Corrosion.—The various steel parts on aircraft, and especially these spars and ribs built up from thin steel strip, should be adequately protected against corrosion. It has been found that the most satisfactory process which can be employed is that known as electro-zincing or electro-galvanising. The metal parts should be very carefully cleaned before depositing the zinc, and the coating of zinc should be approximately 0·001 in. thick. An alternative method is to protect the steel by stove enamelling, after the various parts have been carefully cleaned.

In conclusion I desire to express my grateful thanks to General R. Brooke, Popham, C.M.G., R.A.F., for the permission given to read this paper, and to my former colleagues, especially Professor F. C. Lea ; Major H. N. Wylie, R.A.F. ; Major J. Goodman, R.A.F. ; Major A. Robertson, R.A.F. ; and Mr. W. D. Douglas for the ready assistance always given in the discussion of the various difficulties as they arose.

My best thanks are also due to all the aircraft firms mentioned for the generous manner in which they have furnished for our benefit the various drawings and photographs of the aeroplane parts, together with the experimental data obtained.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Anxiety as to supplies immediate and for the early future, is responsible for a widespread concentration of interest in the market for raw and finished materials. Current deliveries are in many cases barely sufficient to meet requirements, and the difficulty respecting forward commitments is becoming increasingly apparent. There seems to be no end to the rise in quotations. Prices of practically every class of the basic iron and steel have advanced again this week. Record figures have been reached in the steel billets section, where, following a rise of 30*s.* a ton, an extra 2*l.* per ton has been added, making the current level of prices the highest in the history of the Sheffield steel trade. Siemens acid billets cannot be obtained at less than 29*l.* 10*s.* a ton, and Bessemer acid billets at 26*l.* It is expected that the quotations for hard and soft basic billets will be adjusted in proportion. Contemporaneously an advance of 2*l.* a ton is notified in South Yorkshire bar iron, and 3*l.* in hoops. Bars now stand at the unprecedented level of 26*l.* 10*s.* a ton, steel hoops at 34*l.* 17*s.* 6*d.* and iron hoops at 35*l.* 2*s.* 6*d.* Values of common irons are very unsettled. It is practically impossible to obtain a firm quotation. Basic pig-iron is somewhere about 12*l.* a ton, and foundry iron 11*l.* 2*s.* 6*d.* Makers are readily disposing of the whole of their current output, and in most cases are booked up well ahead. Sheets are almost unobtainable, even at the high price of 24*l.* and 25*l.* Producers and consumers alike declare that defective transport is the primary cause of the undoubted shortage. In Sheffield, an effort is being made to meet the steel scarcity by mass production of billets. One firm has installed the very latest plant capable of producing 10,000 tons of billets per week. So far as foreign supplies of material are concerned, deliveries of Swedish iron and steel are coming to hand with greater regularity, but here again prices are materially on the up grade. A fair tonnage of Swedish billets, bar iron, and pig-iron is going into consumption in South Yorkshire. The crucible steel branch is rapidly coming into line with the rest of the trades. Overseas countries are again buying high-speed tool steels with greater liberality. Orders for railway steel have, during the last six months, come in with such freedom as to fill up makers' books. Manufacturers in all branches of the lighter branches, tools, wire rope, implements, &c., are wrestling with a world-wide demand and have no anxiety with regard to sales for the whole of the coming year.

South Yorkshire Coal Trade.—Open market business is necessarily restricted to a very limited tonnage, owing to the tremendous demand on contract account. Best steam hards are a very strong market. All kinds of home consumers are pressing for allocated tonnages. The continued shortage of trucks seriously aggravates the position. Cobbles, nuts and slacks are practically all absorbed on contract account. The bulk of the output is going away in traders' wagons to home users. Slightly easier conditions prevail in the house-coal section pressure by consumers being diminished with the advent of warmer weather and longer days. The demand for coke of all qualities continues in excess of supplies. Quotations :—Best branch handpicked, 23*s.* to 24*s.* ; Barnsley best silkstone, 23*s.* to 23*s.* 6*d.* ; Derbyshire, best brights, 21*s.* to 22*s.* ; Derbyshire house coal 18*s.* 6*d.* to 19*s.* ; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.* ; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.* ; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.* ; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.* ; rough slacks, 24*s.* to 25*s.* ; nutty, 23*s.* 9*d.* to 24*s.* ; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—To secure the equitable distribution of supplies of Cleveland pig-iron to Scotland the ironmasters favour the revival of a system of allocation to customers North of the Tweed. Demand

on behalf of consumers in Scotland, as well as on behalf of other home customers, is unabated, and inquiry on foreign account continues very heavy. Supply is altogether inadequate, but the shortage appears to be slightly less acute than it has been, and it is gratifying to learn that a trifle more iron is available for shipment. For home consumption, No. 1 is 212*s.* 6*d.* and No. 3 and the lower qualities are 200*s.*; and for shipment to France, Belgium and Italy, the former is 217*s.* 6*d.* and the latter are 205*s.* Very high rates are named for iron for other destinations abroad, and a parcel of siliceous is reported to have been sold to the Far East at 290*s.*

Hematite Iron.—The East Coast hematite branch presents no new feature of moment. Very little iron can be spared for export, and makers are by no means anxious to book further home orders. To home customers, No. 1 is 262*s.* 6*d.* and mixed Nos. are 260*s.*, and the quotations are 267*s.* 6*d.* and 265*s.* respectively for despatch to France, Belgium and Italy; while for shipment to neutrals, No. 1 is in the neighbourhood of 280*s.* and mixed Nos. are round about 277*s.* 6*d.*

Foreign Ore.—Sellers of foreign ore take a very firm stand, but consumers are very disinclined to pay prices asked. Market quotations are based on a minimum of 50*s.* for rubio of 50 per cent. quality, on the 17*s.* parity freight Bilbao–Middlesbrough, and as chartерings from the Spanish ore port are being made at 37*s.* the c.i.f. Tees value of best rubio is quite 70*s.* Several sellers ask a shilling or two above such terms.

Coke.—Coke keeps very scarce, and local consumers are quite prepared to pay the advanced rates of 55*s.* 6*d.* at the ovens for average blast-furnace kind and 58*s.* at the ovens for low phosphorus sort.

Manufactured Iron and Steel.—Conditions in finished iron and steel are unrelieved, and the chief concern is to secure delivery of supplies already contracted for. Most manufacturers are so busily employed and so much in arrears with deliveries that they cannot entertain business offering. The following are among the principal market quotations: Common iron bars, 20*l.*; marked bars, 28*l.*; steel ship, bridge and tank plates, 22*l.*; steel ship angles, 21*l.* 10*s.*; rivets, 33*l.*; steel boiler plates, 28*l.* 10*s.*; packing steel (parallel), 18*l.* 5*s.*; packing steel (tapered), 22*l.* 10*s.*; steel strip and hoops, 27*l.* 10*s.*; soft steel billets, 21*l.*; hard steel billets, 22*l.*; steel joists, 21*l.* 10*s.*; heavy steel rails, 21*l.*; fish plates and sleepers, 26*l.*; black sheets, 45*l.*; and galvanised corrugated sheets, 55*l.*

Messrs. Dorman, Long and Co.'s New Issue.—The decision of the directors of Messrs. Dorman, Long and Co., Limited, to issue new capital, was not at all unexpected. The shareholders are to be asked on Tuesday next to sanction the issue of 3,000,000 ordinary 1*l.* shares, to be offered to the present shareholders, who will be entitled to take up the new issue according to the amount of present holding. This will bring the capital of the huge Middlesbrough undertaking up to 7,500,000*l.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Continued activity is general in the steel trade of Scotland and makers, while confining themselves still almost wholly to supplying the home trade, are even finding great difficulty in keeping abreast of the very heavy demand which prevails. The trade boom throughout the land requires an enormous amount of steel material at the present time to satisfy its requirements, with the result that the possibility of expansion in the export branch of the steel industry seems more remote than ever. Advancing prices have failed to cause even a temporary check in buying, or rather the desire to buy, because in many instances it is very difficult to get makers to accept fresh business for delivery under three or four months. Even then no definite promise can be made as to a probable date, and added to that is the condition that the price then current will be the invoice price. The production is limited owing to the shortage of raw material, and is still very far short of actual requirements, and if supplies were only larger and the home demand less pressing a very remunerative business could be done in export. Meantime there is very little material available for shipment abroad, although good prices are being offered. Ship plates which are being turned out in large tonnage find a ready outlet, and deliveries are quickly used up and operations are often hindered through lack of material. Shipyard managements occasionally find themselves almost standing idle owing to delay in delivery of material from the steel works. The position now is that makers are not accepting fresh orders for ship plates for months ahead. A similar state of affairs exists in the black sheet trade, and some very good specifications have lately had to be returned as makers could not entertain them. The demand is exceedingly heavy and shows no signs of slackening off. For galvanised sheets there is also a big outlet, and buyers are pressing for deliveries. Sectional material is again in strong demand, and producers are being kept steadily employed. Prices are very stiff and look like advancing much higher than the present level.

Malleable Iron Trade.—In the malleable iron trade of the West of Scotland an urgent demand exists for deliveries against orders placed some time ago, but there is a shortage of stuff and all orders have to be taken in rotation. The high price has had no effect in the way of keeping buyers out of the market, and many lines representing a large tonnage have been going around this past week, but makers are all so full up that little more can now be booked for months to come. The basis price for "crown" bars is now called 26*l.* per ton, net, Glasgow station, but even that figure hardly seems stable.

Scotch Pig-Iron Trade.—With the home trade so busy and consumers gasping for stuff, Scotch pig-iron makers are being kept as busy as it is possible to be. The demand is very heavy for all grades of iron, and in the case of No. 1 foundry the supply is very scarce. Prices are very strong, but buyers seem prepared to pay even more could they but secure early delivery, as it is the matter of delivery which counts most nowadays. In the matter of export there is not much being done, and for what is available sellers quote round 14*l.* 5*s.* per ton, f.o.b. Deliveries of hematite to the steel works are fairly good, but the consumption is on a large scale.

General Trade.—The general trade of Glasgow and the West of Scotland is exceptionally good at the present time, but shortage of supplies of raw material is rather a serious matter with which producers have to contend. Fuel supplies are also rather bad and are often of a hand-to-mouth nature. The engineering works are all busily employed, and makers of agricultural machinery have any amount of work on hand. Tube makers are also experiencing active conditions, and prices have advanced, while nail manufacturers have the offer of more orders than they could possibly face for a long time to come.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—The outlook is very unpromising. The South Wales miners have decided not to accept a 3*s.* per shift increase for adults and 1*s.* 6*d.* for boys which has been put forward by the Miners' Federation of Great Britain, and intend pressing for an advance of 2*l.* per week. The price of bunker coal for steamers in the foreign trade have been fixed as from to-day by a voluntary arrangement on the part of the coal owners at 80*s.* for large, of which there is to be 75 per cent., 60*s.* for smalls, of which there is to be 25 per cent., and 75*s.* for throughs, which in the case of large means a reduction of from 30*s.* to 35*s.* per ton on current market prices. Foreign vessels are also to have the benefit of this reduction, a step which is adversely criticised by operators in view of the fact that the change in effect means a subsidy of 23,000,000*l.* per annum to lower freights. In view of the very uncertain labour outlook export business remains virtually at a standstill as collieries are full up with allocation orders to home consumers, and have practically nothing for sale on the open market. At the same time there are something like 500 vessels in Cardiff, Penarth, Barry and Newport waiting for coals which shippers are not able to get released. In fact, the quantity of coal arriving at the docks for shipment is not sufficient to keep all tipping appliances fully employed, and even at those at which boats are loading lengthy delays are experienced in "waiting for coal." Though production this year has several times exceeded 1,000,000 tons per week for the first time since the introduction of the 7-hours' day in July last, foreign exports last week were the smallest for any single week in the current year. They totalled only 268,720 tons, of which 164,114 tons went to France, equal to 61 per cent., and 20,870 tons to Italy, or 8 per cent. of the total. Prices show no quotable alteration, and are firm at 110*s.* to 115*s.* for large, 105*s.* to 110*s.* for throughs, and 90*s.* to 97*s.* 6*d.* for smalls. Coke for export is very scarce and realises up to 175*s.*, while patent fuel is also in short supply and worth from 120*s.* to 125*s.*

Iron and Steel Trades.—Business generally has been quieter of late and prices easier, notwithstanding the advance of 40 per cent. to steel workers. For stock plates, 77*s.* f.o.t. at works is quoted, whilst for May and June delivery 75*s.* to 76*s.* is asked, and 73*s.* for July–September. The immediate cause of the lower quotations is a set-back in the price of tin. Mills are not in full operation, and with the Easter holidays near it is expected that there will be an early recovery in prices. Galvanised sheets are firm at 50*l.* for 24-in. gauge corrugated sheets. Steel bars are 5*l.* up, at 30*l.* to 35*l.* per ton.

UNIVERSITY COLLEGE, LONDON, ENGINEERING FUND.—The proposals for the reconstruction and re-equipment of the engineering buildings at the University College, London, were explained on Friday last at a luncheon held at the Savoy Hotel and presided over by H.R.H. Prince Arthur of Connaught. As stated in our issue of the 12th inst., on page 342, where we dealt fully with the proposed reconstruction, a sum of 100,000*l.* is required for the work, and, of this amount, about one-third had been received, or promised, at that time. His Royal Highness announced that, during the week preceding the luncheon, further donations totalling 4,250*l.* had been received, so that there should be no difficulty in eventually raising the whole sum. The need for reconstruction, however, was urgent in 1914, so that it is doubly urgent now, and it is therefore to be hoped that donations will be forthcoming with the least possible delay. Sir Gregory Foster, the Provost of the College, stated that the engineering school was crammed to overflowing, so much so that in September last over 100 applications for admission had to be rejected. Even greater difficulties would be experienced in the coming autumn unless the new work could be put in hand. The plans, he said, were all ready, and, if sufficient funds were raised to enable a start to be made within the next few weeks, a considerable section might be ready for occupation by October next. For this reason we would remind our readers that *bis dat qui cito dat.* Donations may be sent direct to H.R.H. Prince Arthur of Connaught, at 42, Upper Grosvenor Street, London, W. 1.

NOTICES OF MEETINGS.

THE KEIGHLEY ASSOCIATION OF ENGINEERS.—Saturday, March 27, in the Assembly Room of the Cycling Club, a lecture will be given by Mr. Harry Sherburn, of the British Foundrymen's Association, Warrington. Subject: "Iron Foundry Practice." Chair to be taken at 6.30 p.m. by Mr. H. R. Shackleton.

THE RÖNTGEN SOCIETY.—Tuesday, March 30, at 8.15 p.m., General Meeting in the X-Ray and Electrical Departments of St. Bartholomew's Hospital, London, E.C. Agenda: Minutes of the last Meeting, Nominations and ballot.

THE ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN.—Tuesday, March 30, at 7.30 p.m., at the Arts Building, Liverpool University, Mr. S. Clowes, Wh.Ex., on "Elementary Calculus," being the concluding lecture of the series.

NORTHERN FRANCE COLLIERIES.—The Société des Ingénieurs Civils de France have issued an illustrated pamphlet reproducing the address delivered recently by their new president, Mr. E. Gruner, and giving detailed particulars of the systematic destruction by Germany of the collieries in Northern France.

CONTRACTS.—Messrs. Clayton and Shuttleworth, Limited, Lincoln, state that orders recently placed with them for "Clayton" steam wagons come from Devon County Council, Elland Urban District Council, Redditch Urban District Council, West Riding of Yorkshire County Council, Dundee County Council, Northampton Borough Council, Derby Borough Council (2).

THE LATE MR. CHARLES CHITTICK.—We regret to have to record the death, which occurred at his residence, Bournemouth, on February 25, of Mr. Charles Chittick, permanent director and chairman of Matthew T. Shaw & Co., Ltd., constructional engineers, Millwall, E. Mr. Chittick commenced his career at Woolwich Arsenal; he then entered the Thames Ironworks & Shipbuilding Co., Blackwall. In 1871, he obtained the position of general manager to the firm of Matthew T. Shaw & Co., becoming a partner in 1880. In 1881, the firm built and equipped under his supervision new works at Millwall; these have since been considerably en arged and modernised. After the death of Mr. Matthew T. Shaw in 1886, the business was continued by Mr. Harry T. Shaw and Mr. Chittick until 1895, when it was incorporated as a private limited company. Mr. H. T. Shaw retired in 1906, and Mr. Chittick continued as managing director until 1908, when he relinquished the active management, retaining the position of permanent director and chairman, and devoting much of his time to the company's business in an advisory and consultative capacity.

PERSONAL.—Messrs. J. Blakeborough and Sons, Limited, Woodhouse Works, Brighouse (Yorkshire), state that they have opened a London office at Kingsway House, Kingsway, London, W.C. 2; their telephone number is Gerrard 3568, and their telegraphic address "Akeborobla, Phone."—Messrs. Handley Page, Limited, state that they have been appointed sole agents to the Aircraft Disposal Company, Limited, who have purchased the entire surplus stock of British aircraft.—Messrs. Johnson and Phillips, Limited, state that their Cardiff branch address is now removed from 9, Park-place, to 2A, Court-road; their telegraphic address and telephone number remain as before.—Messrs. Handcock, Dykes & Trotter, Consulting Engineers, of 11, Victoria Street, Westminster, S.W. 1, announce that, owing to the decision of Mr. A. P. Trotter to retire to the country, where he will devote himself to his special scientific subjects, the firm will, from the 25th instant, resume the old name of Handcock & Dykes, under which it was founded in 1894.—We are informed that Cuirass Products, Limited, manufacturers of anti-rust paint, &c., have removed to 69, Victoria-street, Westminster, S.W. 1. Their telephone number is Victoria 5419.

SIAM: NEW RAILROAD DEVELOPMENTS.—The British Consulate-General at Bangkok reports to the Department of Overseas Trade that a Royal Decree by the King of Siam was promulgated on the 16th inst., ordering that a survey should be made and land acquired with a view to the construction of a short railroad to link up the northern and southern railway systems at Bangkok. At present, the respective termini of the above two systems are situated on opposite banks of the River Menam, with no means of connection between them. The new railroad, unimportant in itself, is chiefly interesting as being designed to form the approaches to a bridge which it is intended to build across the Menam in due course. It is understood, however, that the construction of the bridge will not take place in the immediate future. Connection between the southern and northern railway systems follows as a corollary of the proposal to convert the latter from a broad-gauge railroad into a line with a gauge of 1 m. By this means the northern system will be brought into uniformity, not only with the Siamese southern system, but also with the systems in the Federated Malay States and the Straits Settlements on the west and in French Indo-China on the east. It is proposed to begin the work of conversion in 1921. New rolling-stock for the northern system will, of course, be required, and tenders for its supply will probably be issued at the end of this year. Apart from the question of conversion, the Siamese Railway Department is in great need of fresh rolling-stock to replace losses which it was not possible to repair during the period of the war.

GEARED TURBINES OF H.M. BATTLE-CRUISER "HOOD."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, CLYDEBANK.

(*For Description, see Page* 397.)

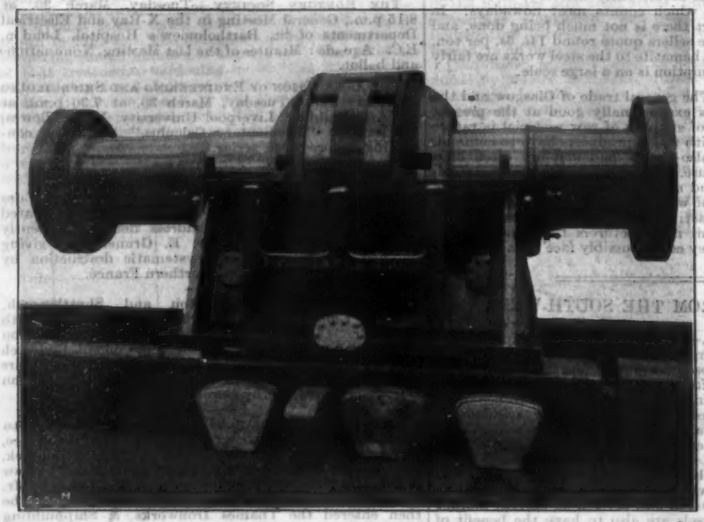


FIG. 13. MICHELL THRUST BLOCK WITH CAP REMOVED.

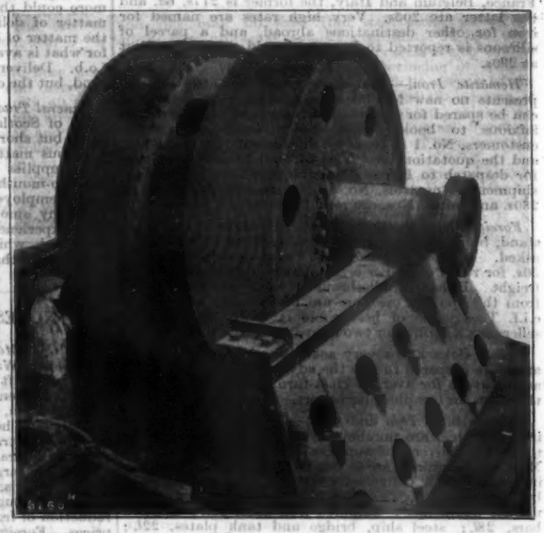


FIG. 14. DOUBLE HELICAL SPUR WHEEL FOR REDUCTION GEAR.

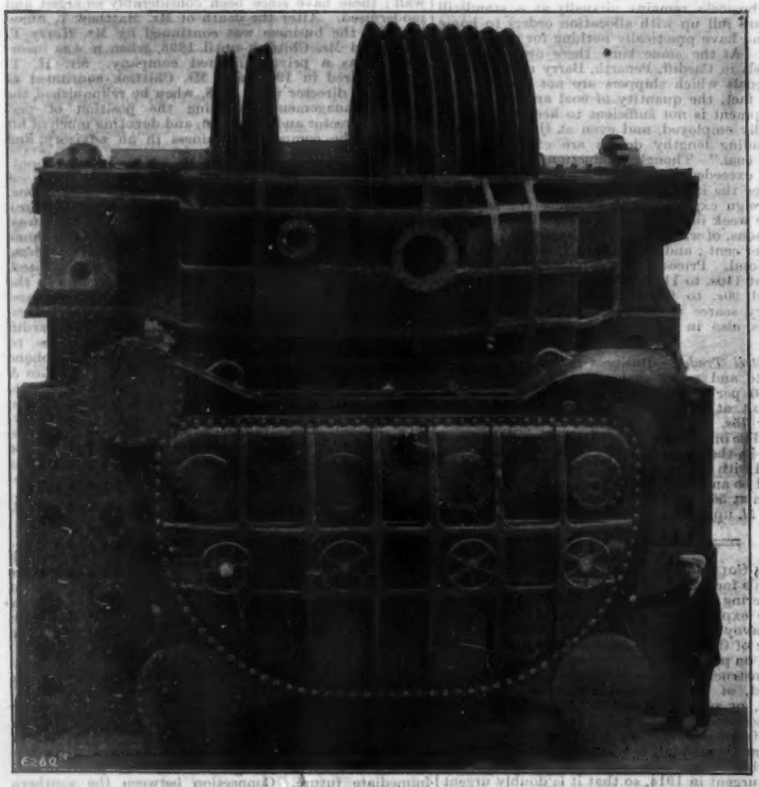


FIG. 15. LOW-PRESSURE AND REVERSE TURBINE WITH CONDENSER BELOW.

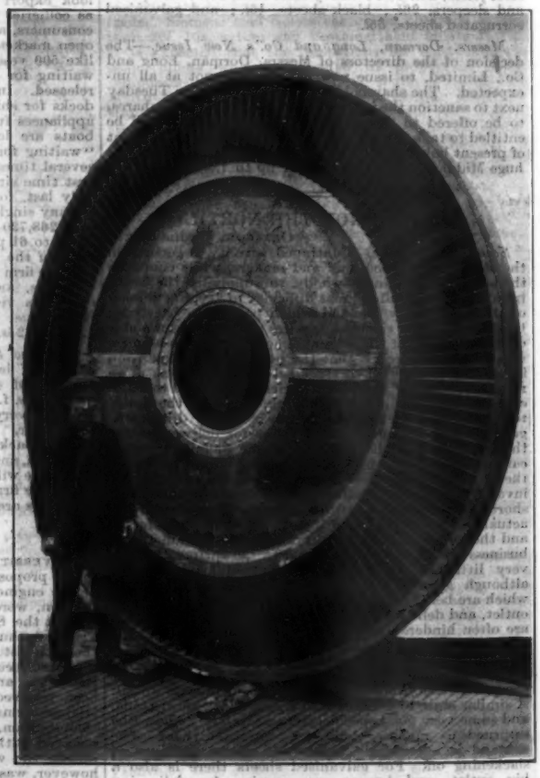


FIG. 16. DIAPHRAGM FOR LOW-PRESSURE TURBINE.

THE PURCHASE OF SURPLUS AIRCRAFT MATERIAL.—With reference to the announcement which appeared in the Press regarding the large transaction in British aircraft, the syndicate interested is the Aircraft Disposal Company, Limited, by whom the following announcement has been made. "The sale by the Government of all its surplus aircraft material, engines, spares and accessories was completed at the end of last week. We did not purchase direct from the Government, but we have now taken over the whole of the benefits and liabilities of the purchasers. The company which comprises widespread British interests, has been specially formed to carry on the whole of the work previously undertaken by the Ministry of Munitions in disposing of the surplus stocks of heavier-than-air machines and equipment. Offices have been taken in Kingsway and, as rapidly as possible, the organisation will remove there from the present Disposal Board offices. The whole of the storage organisation and the management of the large aircraft depots all over the country will pass into our control. The Disposal Board, since the armistice, have sold large numbers of machines, but their potential sales have been very much handicapped by their limitation to selling machines as they stand. Many of the machines for disposal are quite new, but in order to ensure that every machine, engine, accessory and spare is in perfect condition detailed inspection will take place before delivery, and certificates of airworthiness will be given for all machines sold. Messrs. Handley Page, Limited, are members of the syndicate, and we shall have the full advantage of their experience in aircraft matters, as they will act as our technical advisers and be our sole agents for the disposal of the material."

HIS MAJESTY'S BATTLE CRUISER "HOOD."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, CLYDEBANK.

(*For Description, see Page* 397.)

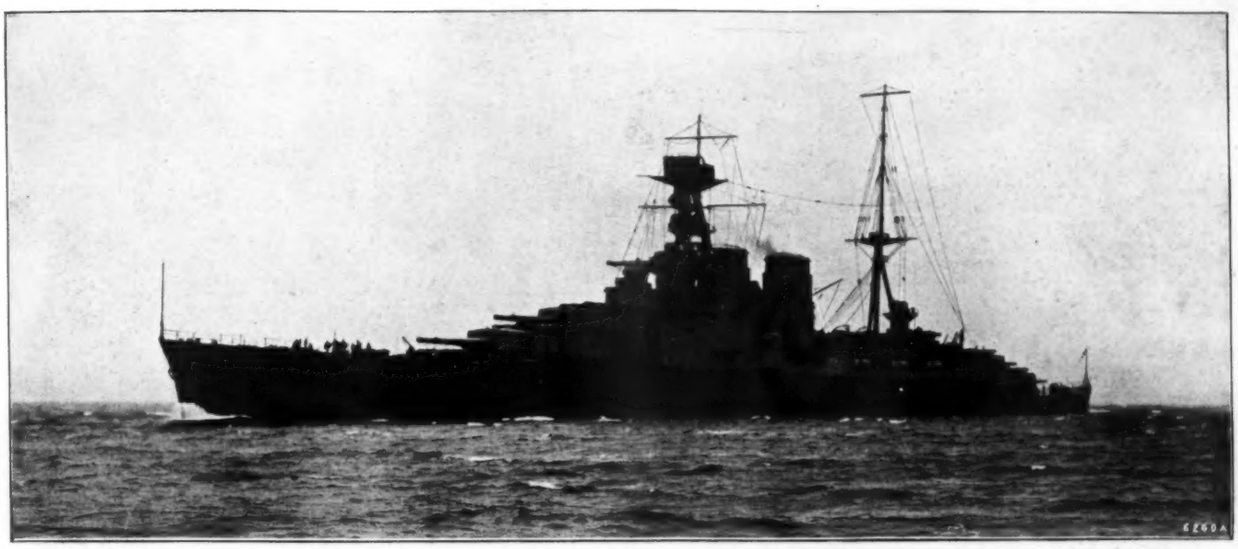


FIG. 3. THE "HOOD" STEAMING AT CRUISING SPEED.

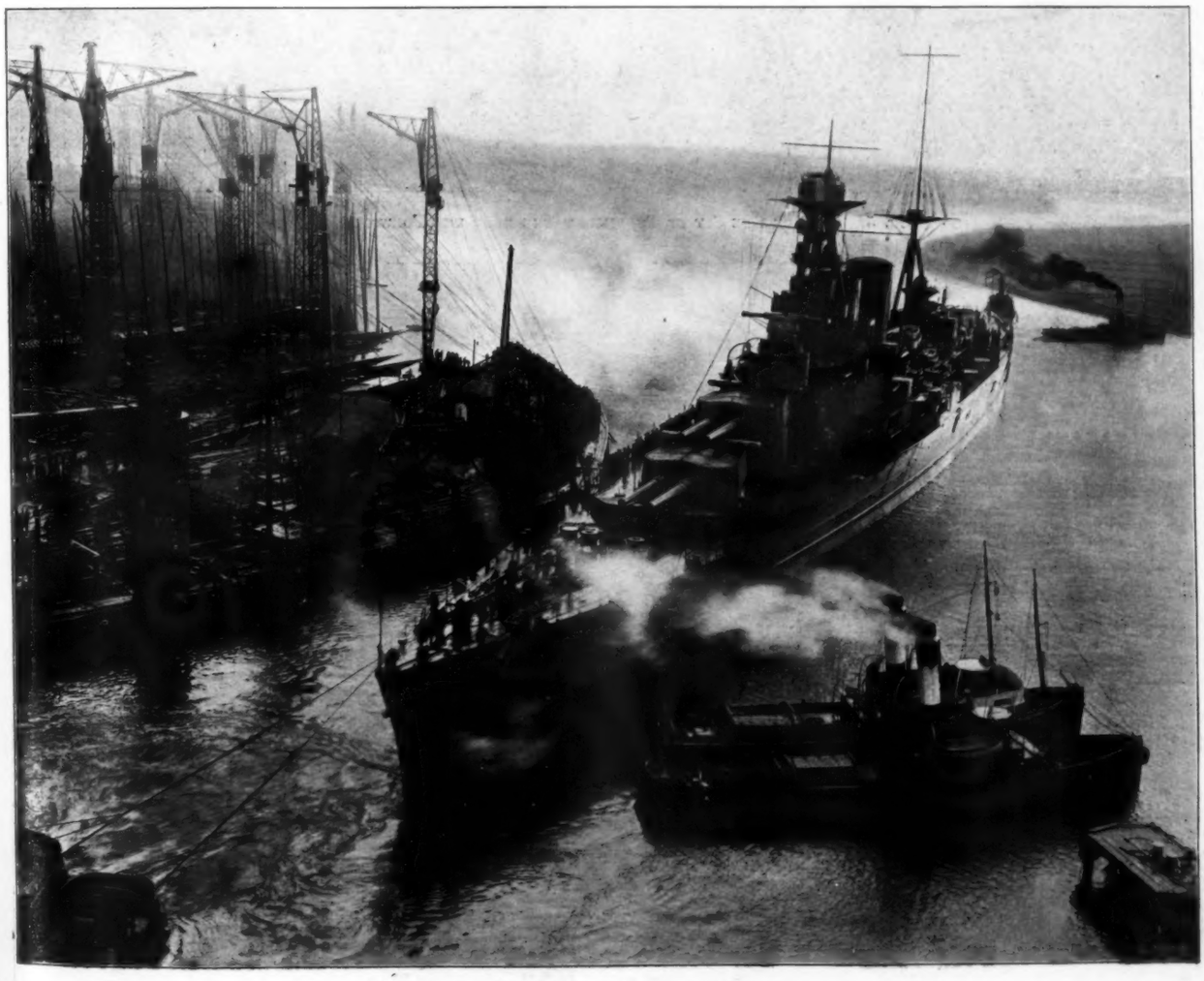


FIG. 4. THE "HOOD" LEAVING THE DOCK AT CLYDEBANK.

(*To face page* 398.)

GEARED TURBINES OF H.M. BATTLE CRUISER "HOOD."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, CLYDEBANK.

(*For Description, see Page* 397.)

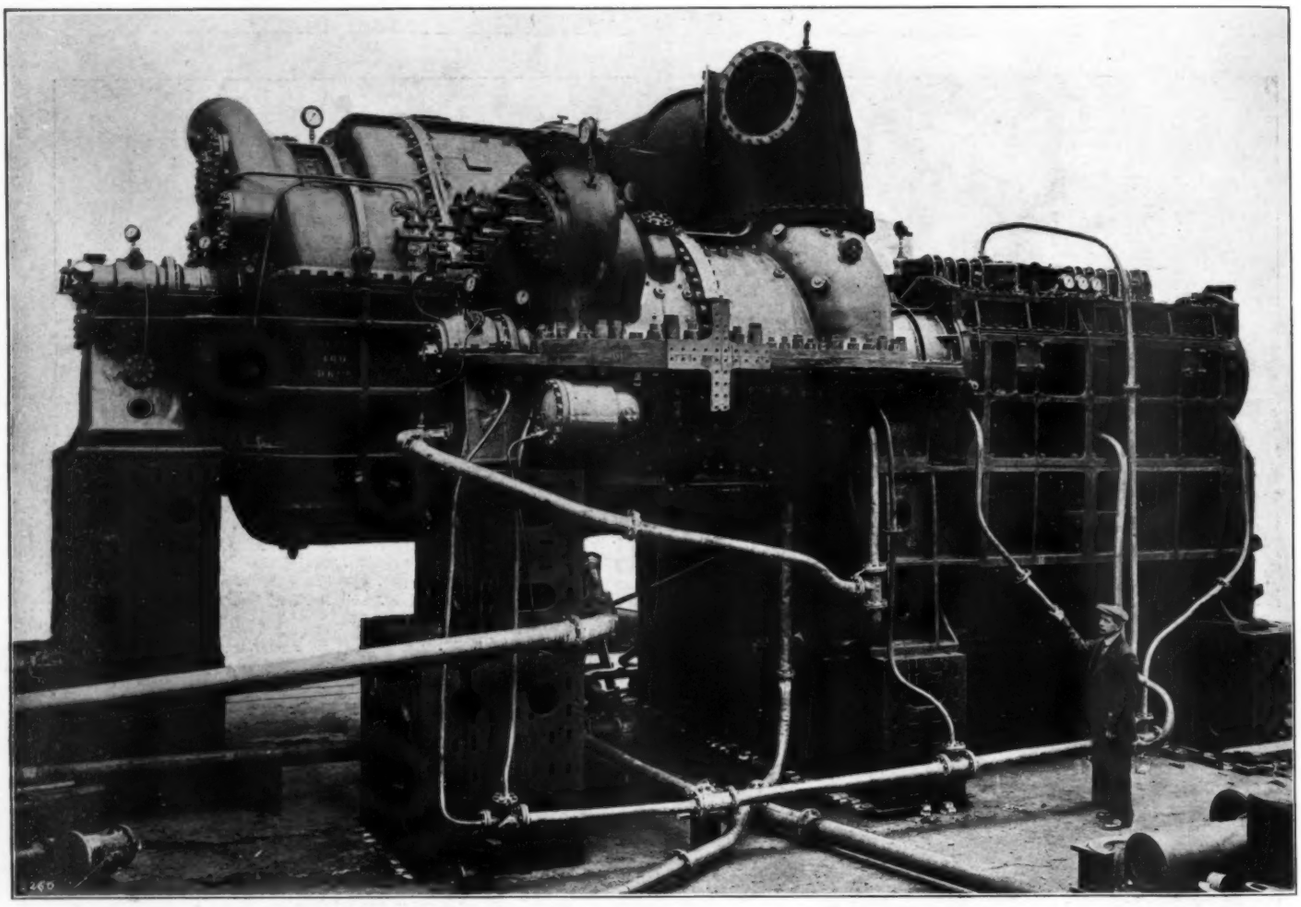


Fig. 5. View of One Set of Turbines taken from the Forward End.

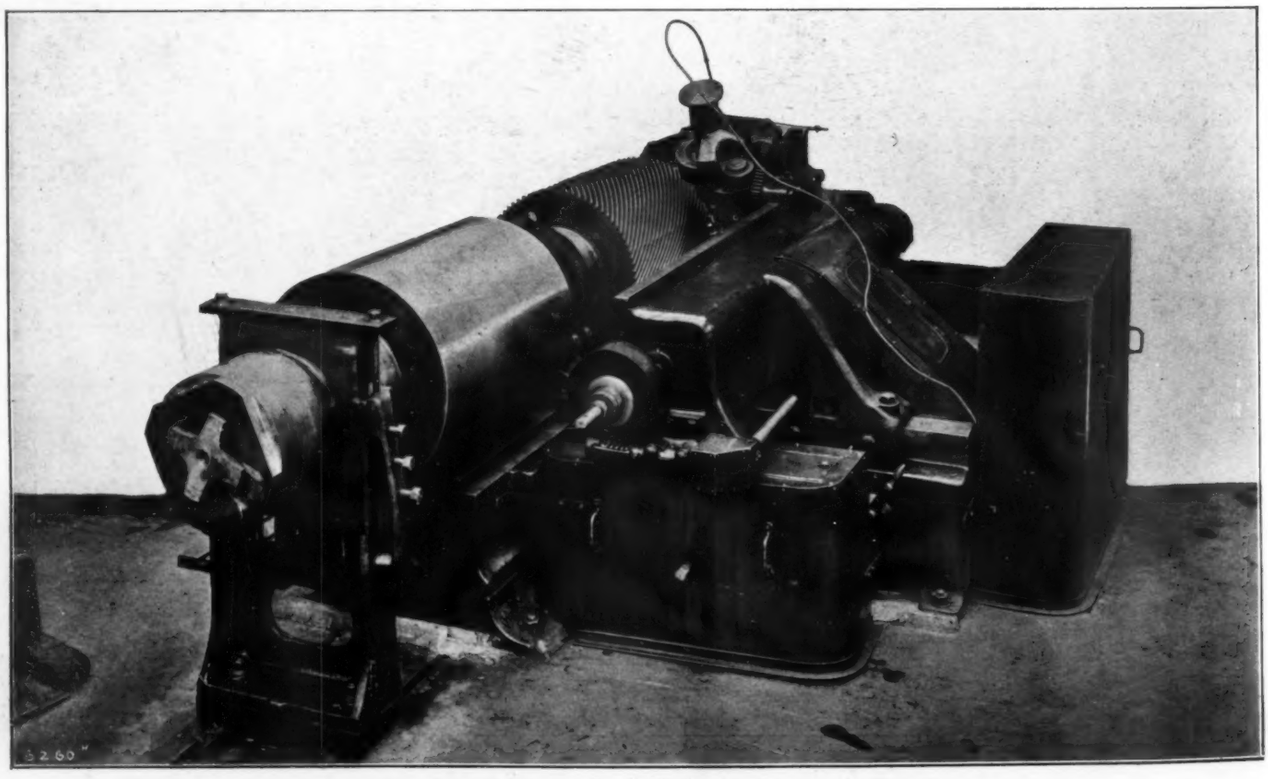


Fig. 6. Hobbing one of the Helical Pinions.

GEARED TURBINES OF H.M. BATTLE CRUISER "HOOD."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, CLYDEBANK.

(*For Description, see Page* 397.)

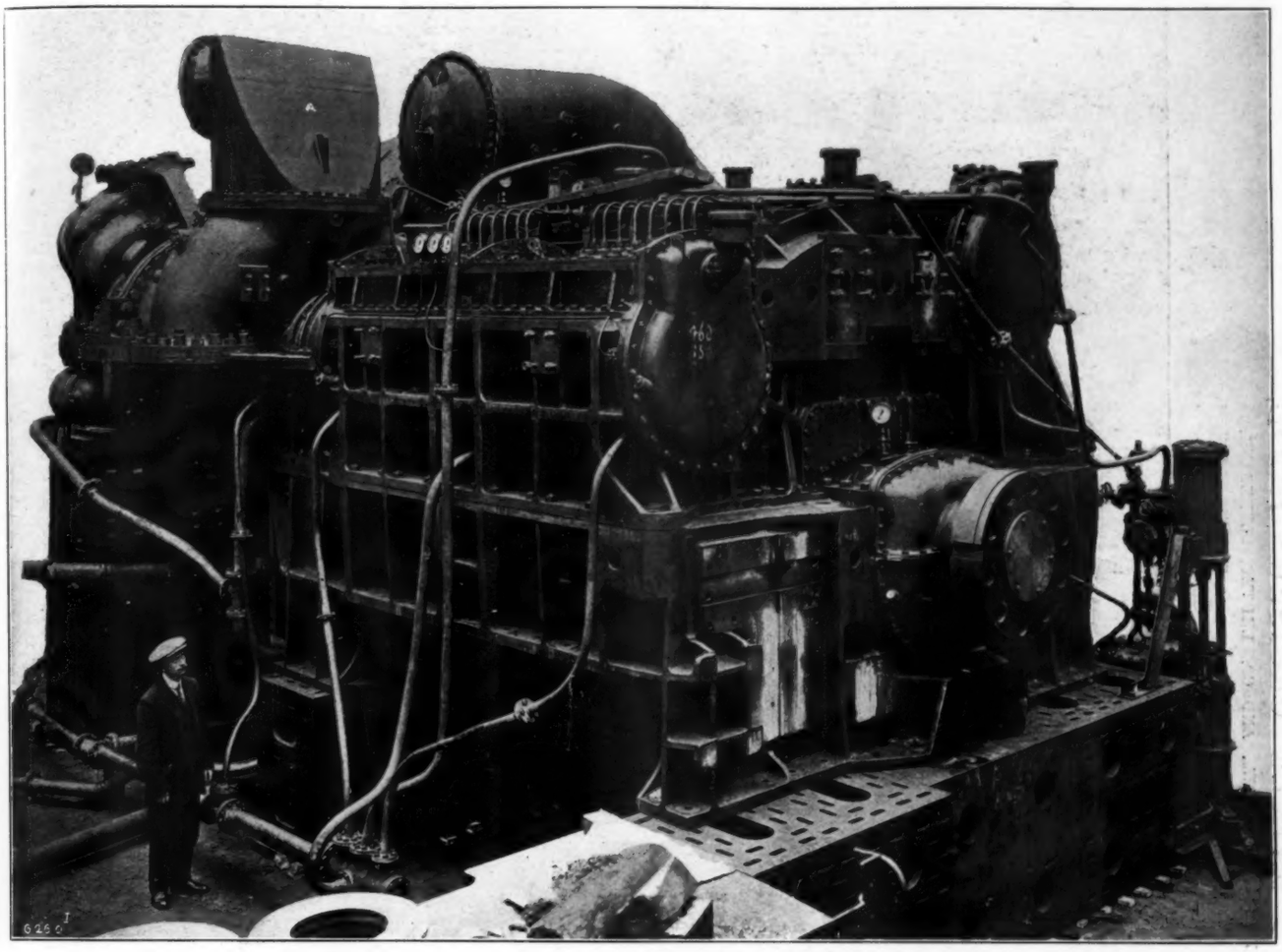


Fig. 7. View of Turbines and Gear Casing taken from the After End.

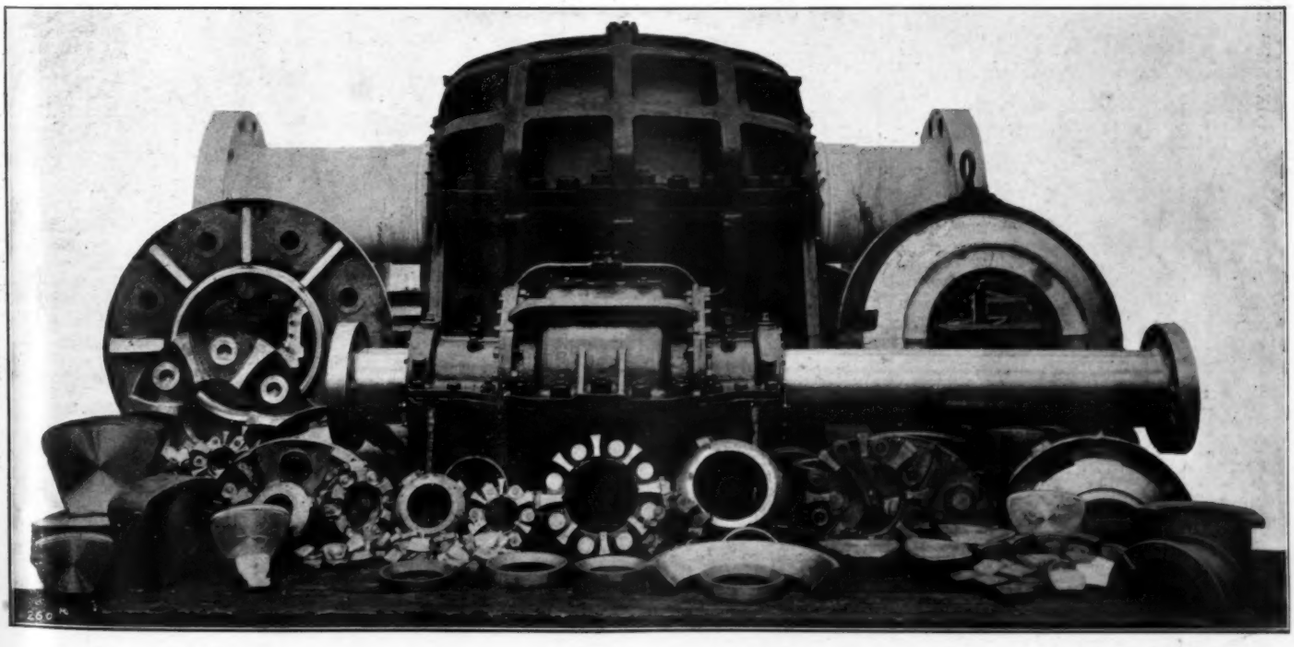


Fig. 8. Michell Thrust Block for "Hood" and Parts. In the Foreground a similar Block for a Destroyer.

HIS MAJESTY'S BATTLE CRUISER "HOOD."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, CLYDEBANK.

(*For Description, see Page* 397.)

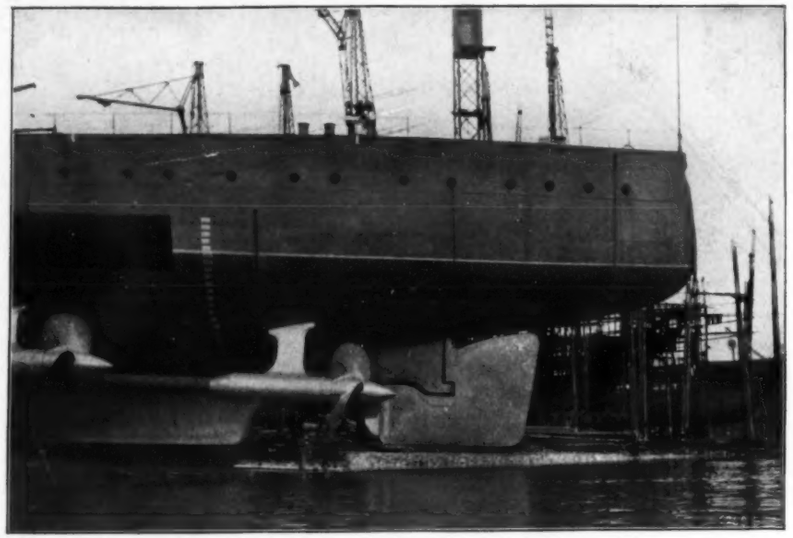


FIG. 9. VIEW OF STERN, SHOWING BALANCED RUDDER.

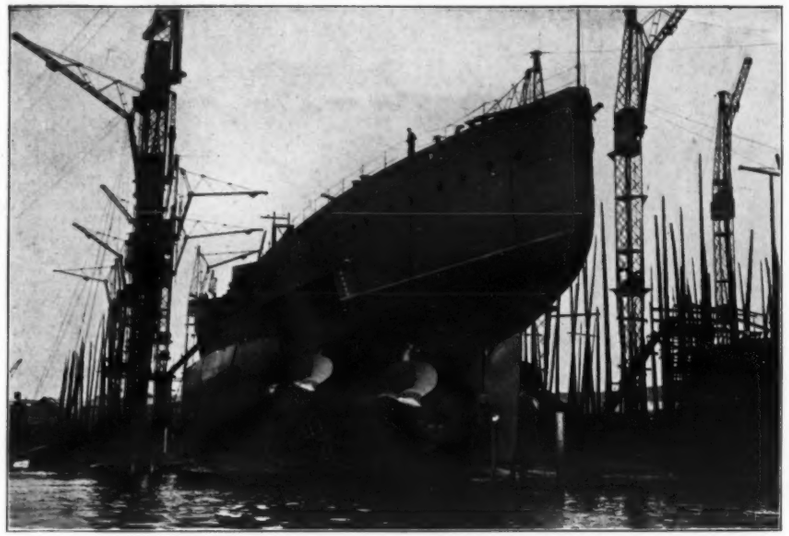


FIG. 10. STERN OF VESSEL JUST BEFORE LAUNCHING.

FIG. 11. PROPELLER SHAFT BRACKETS BEING ERECTED IN PLACE.

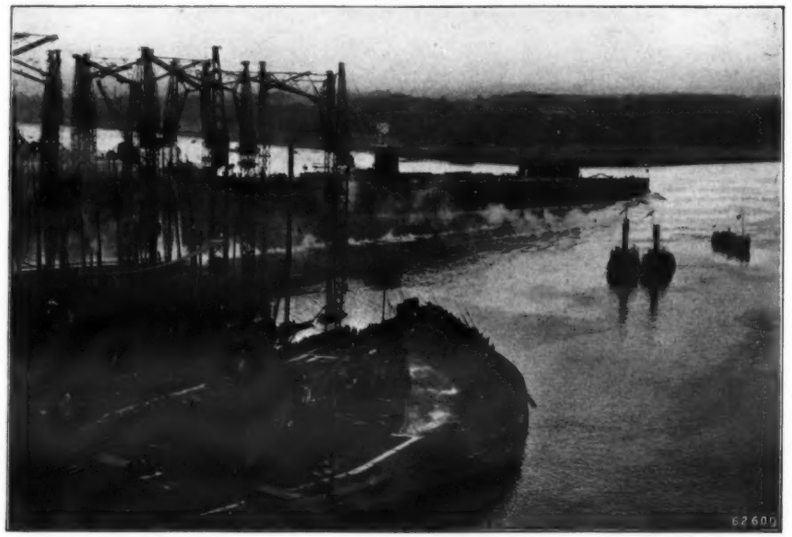


FIG. 12. THE LAUNCH OF THE "HOOD."

(*To face page* 399.)

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The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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For Canada—	
Thin paper copies	£2 18 6
Thick ,, ,,	£3 3 0
For all other places abroad—	
Thin paper copies	£3 3 0
Thick ,, ,,	£3 7 6

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3068 and 3069 GERRARD.

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With Four One-Page Plates of HIS MAJESTY'S BATTLE CRUISER "HOOD."

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price will date from and include the issue of Friday, April 2, 1920. So long as postal rates remain as at present there will be no increase in the price of copies sent by inland post, which will continue at 1s. 2d., post free.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 413.

ENGINEERING.

FRIDAY, MARCH 26, 1920.

THE PENALTY OF RETICENCE.

THERE is no doubt that much of the trouble in this world arises from narrowness of view born of ignorance. The great idea of people "getting together," as the saying is, has this at the back of it, the benefit possible from a better mutual understanding. The laudable attempts now being made in industry fowards a *rapprochement* between employers and employees is the result of a realisation, all too recent, that classes of the community have been, for many years, undergoing a restricted form of education, in which stress has been laid on one or two particular points to the detriment of the sense of general balance and proportion. In the admission of labour representatives to various boards the benefit should be common to both parties. It is extremely easy to criticise when one has only one side of a case to go on, and the party which talks loudest soon gets a strong following among people unable to get their information from better sources. It is much more difficult for a man with any conscience to make a strongly biased argument when he has been compelled by his position to face the real, and not imaginary, facts, of the other side. The dissemination of real facts is, therefore, a safeguard. Further, to the employer the position of the average worker should become more familiar, for, in spite of all, in all great industries a gulf inevitably arises as enterprises grow, between the employer and the workers. It is a matter of deep regret that this is unavoidably so. There are few labour troubles where the works are small enough for the employer to know his men personally. But with prosperity extra business keeps the employer more to the office, attending to administration, while the foremen gradually step in between. The gap widens as time passes and business increases till the bulk of the men are all but unknown to the manager, who comes to be regarded by the men, not as one of themselves, but as a man apart. Then, unwittingly, the suspicion arises that the latter cares no longer for his men, but mainly for himself, and the seeds of discontent are sown to spring up later into all sorts of troubles about wages and hours and conditions of working.

It is this suspicion, bred of ignorance, that Sir Eric Geddes considers to be at the root of much of our transport difficulties to-day. At the inaugural meeting of the Institute of Transport held on Monday last in the theatre of the Institution of Civil Engineers, the Minister of Transport, fittingly first president of the new Institution, made this the theme of part of his address. Sir Eric Geddes reviewed the attitude of the country, before the war, towards our great transport systems. At that time the railways, whatever action they took, were regarded with suspicion. They were held to be huge capitalist organisations of which the profits went still further to enrich the wealthy. They were considered to be so badly managed that it was deemed possible for any outsider to be capable of pointing out numberless obvious economies. It was said that redundant services ought to be curtailed, yet, when the companies began to group themselves together to effect operating economies, the plans met with most vehement opposition. The demands of labour were constantly out of all proportion to the net profits on the capital invested in railways, and it is only recently that labour leaders have been brought to see the necessity of some correlation in this direction. This condition has only been arrived at by placing fairly before the unions the exact financial position of the undertakings. If the divulgence of such facts really tends to sweep away some of the unrest, by all means let us have more of it wherever possible.

Sir Eric Geddes, we consider rightly, takes the matter further. The railways have had the privilege of having their rates revised with a view to putting them once again on a sound footing—it does not matter for the moment that the present revision is not intended to be final. As the railways are semi-public services operating under a form of public control, the Minister of Transport considers that, having been granted this concession, the companies should have no objection to having the other terms of the virtual contract revised concurrently. It is quite properly pointed out that in return for rate revisions the public has every right to ask that the railways shall be conducted as economically as possible, and shall provide the best service possible for the traffic.

Under the present system of control the Ministry of Transport is the centre of this economic system. It is a perfectly fair ideal to make the Ministry thus answerable to the public for transport, though this development is, it must be admitted, fraught with dangerous possibilities. The Ministry should be able, if it is to warrant its expense, to save a good deal to the country by co-ordinating services, by diverting traffic to suitable routes, encouraging economical developments, &c. Although there were many cases where the highest ideal was not reached, we all learnt the importance of co-ordination during the war, and none better than those engaged in railway transport. But what guarantee is there that the Ministry of Transport will work wholeheartedly with this one end in view. We have not now the same stimulus behind Government departments as existed during the war, and it will be very difficult as time goes on for anybody, even with the driving force of the present Minister, to keep so huge a department from following the common course, and instead of being an active and beneficial force in the affairs of the country, becoming little more than a drain on its resources.

Recently a revised form of railway operating statistics has been published, and Sir Eric, in asking for this fuller information, says that it is by these that the railway system will be judged as to whether or not the public is receiving the economically sound service it has a right to expect. For many years before the war we were among those who were anxious to see information of a more useful character given yearly in connection with our railways. There is now some possibility of getting it, and we hope that with this additional knowledge the confidence in the good management of this huge national industry will be restored. Sir Eric also now claims that the chaos, of which we have heard so much of late, does not exist, and that the railways have lately broken all previous records. It may be they have, but such a statement alone will not clear up the delays and difficulties which have been so prominent in the last six months. We must have more than statements in explanation, and need something constructive. We believe the management of the railways to be sound. If it is the boards have nothing to lose from publicity. It is only the muddler who cannot face the placing of facts before others. His fear arises either because he does not know whether his methods are good, or because he cannot get at real figures. Such men, as Sir Eric says, had better get out and leave the work to others.

We need hardly point out that this talk about publicity cuts both ways. The public has as much right to demand that the frankness which Sir Eric

(To face page 393.)

expects to be ungrudgingly granted by the railways, shall also be characteristic of his own department. The Ministry of Transport is costing the country a pretty penny. What is there to show for it—mainly, at present, a long list of high salaried officials. It is early yet, of course, to pass final judgment. Some have only lately been appointed and have not properly got into their stride, but on the whole the public knows mighty little about what this vast and expensive organisation is doing. It will be recognised that in order to evolve sound and permanent policies for such big things as our road, railway, canal and port systems, a great deal of information is necessary, and this must take time to collect; but it is none the less true that the more this Ministry—which is such an innovation in our country's policy—takes the public into its confidence, laying its cards on the table, and letting it be known what moves it is making in the game, the more likely will it be to secure public support. If, on the other hand, information is reserved for its own files and any attempt is made to keep facts from the country, or if, through arrogance or carelessness, suitable opportunities of publishing accounts of its work are allowed to slip, the country will not be slow in condemning this expansion of bureaucratic control. The new Ministry has to justify itself before the national bar, and publicity with regard to its activities will help it more than secrecy. In these two years it has to make good or it will commit suicide.

The new Institute of Transport, as an agency for ventilating transport matters and discussing problems, should have a prosperous future assured to it. The interests are vast, and the transport business is in the hands of a class of men which ought to make anything but a success an absolute impossibility. The new body has got a good start and we trust that it may soon arrive at a position of authority in the transport world corresponding with the interests involved. May its activities and enterprise ever increase.

THE WEAR OF DIESEL ENGINES.

THE only way to completely dissipate suspicions of unreliability and exaggerated rumours of operating difficulties is by the dissemination of accurate and definite facts of performance. With any new type of prime mover a certain amount of uphill work is inevitable, and must often be borne exclusively by the manufacturer and those responsible for its inception, development and marketing. In the case of the Diesel engine these remarks probably apply more potently than to any other prime mover. Within the last few years the Diesel Engine Users' Association, in the publication of its papers dealing largely with questions of Diesel engine operation, has accomplished most important service and has assisted all who have the interests of this type of machine at heart by the propagation of information relative to Diesel engine operation. This naturally lies most fully in the power of the user to collect. The latest paper read before this Association, "Notes on the Wear of Diesel Engines," by Mr. Jeffrey Porter, A.M.I.C.E., Past-President, contains a very considerable amount of useful data. The most important section is that dealing with the wear of cylinder liners, and concerns primarily that type of engine which is not fitted with a crosshead, but where the trunk type of piston not only serves to keep gastightness, but also takes the side thrust due to the obliquity of the connecting-rod. Records of dimensions at several points in the liner at various periods in the life of an engine, without full particulars as to the nature of the duties and of the other conditions which contribute towards wear, would be of little avail, but in this connection the paper under discussion is not found lacking. All the various factors which enter into this question, except the metallurgical consideration of the type of materials in contact, have been carefully stated. As would naturally be expected, the wear is greatest in way of the top rings, the duty of which is to obstruct the gases at high pressure, and also at that part of the cylinder where the side thrust of the piston is a maximum.

In Mr. Porter's experience, loss of compression occurs when the line of diameter is increased by about 0·05 in. at the point of maximum wear. The wear found by the author is of the order of from 0·02 in. to 0·03 in., and sometimes slightly more per 1,000 hours of running, and a very interesting point is brought out that in many cases the wear of the cylinder is greater parallel to the crankshaft (that is, fore and aft) than at right angles thereto (i.e., athwartships). This is quite contrary to what would be expected, and is explained by the fore-and-aft movement of the crankshaft, due to insufficient arrangements for taking end thrust and maintaining the crank-pins central with the cylinder central lines. With increasing service the rate of wear is found to become slightly greater. In the case of one four-cylinder engine, a rise in the rate of wear was measurable at a position on the inner surface of the liner, corresponding to the band on the cylinder through which the liner is pressed. It is suggested that liners should be renewed when the wear for cylinders up to 18 in. diameter exceeds 0·1 in., and for larger cylinders 0·08 in. Arising from the measurements given in the paper, it is deduced that liner wear is influenced chiefly by the following considerations:—The percentage of ash-content in the fuel, the quality and quantity of the lubricant supplied to the surfaces in contact; the method of lubrication and the fitting of the pistons and piston rings in the liner.

On the subject of quality of material, it is fully realised that this must play a very important part, but this consideration lies outside the scope of the present article. Cases are on record where a very abnormal rate of wear has been attributable to the unsuitable nature of the materials of which the rubbing surfaces were made. The metallurgical aspect of the question of suitable grades of cast iron for piston rings, liners and pistons, has too long been neglected, but is now the subject of considerable research, and it is hoped thereby that not only will wear be considerably reduced, but that uniformity of results can more definitely be predicted. It is, of course, preferable that the piston rings, rather than the liner, should wear, since the former can more readily and most cheaply be renewed. Considerable data are given by Mr. Porter on the subject of piston wear in way of the piston-ring grooves, and in regard to piston rings as well. The formulation of definite laws, as a result of these data, is hardly possible, although an examination of the various measurements goes to show that the accuracy in the machining of these parts, as originally supplied in the case of the engines under discussion, was of a remarkably high order. This remark applies generally to all the particulars given. Some of the figures relating to bearing wear, crank-pin and valve wear are extremely interesting, and are stated with a due regard to the various factors which enter into the question. Altogether, Mr. Porter's paper must serve to give confidence to those contemplating the adoption of the Diesel type of prime mover, as showing that with reasonable care and the requisite high degree of workmanship in construction, and with intelligent operation, comparisons can confidently be made with other types of prime movers working within very much lower temperature limits and lesser pressures.

METEOROLOGY AND THE WAR.

THAT the meteorologist may, together with the engineer and the chemist, claim to have had his share in deciding the war fortunes will perhaps be conceded. But few of the people who listened to the two lectures which Lieutenant-Colonel E. Gold, F.R.S., delivered at the Royal Institution on the first two Thursdays of March, were probably aware to what extent the Meteorological Section of the Army influenced the hour of gas attacks and aeroplane flights, the laying of guns and operations generally. In the early months of the war the Meteorological Office sent its advice from London. When the gas attacks commenced in 1915, a meteorological section was established near headquarters at St. Omer. Stations behind the front were connected by telephone with chief stations further off, and these with the central station; forecasts and directions were issued 4 hours in advance; the distribution of the messages took about an hour, so that the wind direction and force, temperature and humidity of the air, &c., were generally known for 3 hours in advance. The messages, moreover, stated definitely—all by codes—what corrections should be applied to ballistic calculations with respect not only to the surface winds, but also to the winds to be expected in higher strata. In the northern section of France the work was to a certain extent complicated by the fact that the range of hills extending south-east from Calais to Albert and further inland gives rise to a gravitational wind, of which the allied forces were able to make good use.

Various methods were used to determine the wind and other meteorological elements. Small pilot balloons of rubber were generally sent up of such weight and lift as to rise at the rate of 500 ft. per minute; the height at which the balloon would be after a certain time was thus known, and that facilitated theodolite observations. These had originally required one observer and one calculator, the latter filling up his sheet within an hour; that period was shortened to 20 minutes, and the work was very hard. The theodolites, originally fitted with prisms for vertical observation, were provided with mirrors for the less exacting observation in a fairly horizontal direction. The balloons were often frozen stiff, and the men had to warm them on their bodies. For night observations the balloons had to carry lamps, and the staff had been surprised to receive Chinese lanterns from London in November, 1915, and had joked that the time for Christmas illumination had not come yet; but the lanterns had answered, and several men had invented their own lanterns, as they had generally improved apparatus. A small lantern (with candle) sufficed for tracing a balloon at a height of 14,000 ft. Nephoscopes had also served for cloud and wind observations. The late Professor Bertram Hopkinson had devised a method of studying winds above the clouds by means of anti-aircraft shells and aeroplanes. A French officer had dropped explosive charges from a balloon at known intervals, observers down below noting the moments at which the reports of the explosions arrived at different stations. Such methods called for somewhat elaborate calculations, but they had answered well on the whole. Drift indicators, and kite balloons, fitted with anemometers other instruments and telephones, had further been used; care had to be taken, however, lest the anemometer be influenced by the body of the balloon. Various forms of thermometers, meteorographs and hygrometers were specially devised to suit war purposes.

An immense material was thus collected, mostly, of course, under difficult conditions and not always with the desirable accuracy, and that material would carefully have to be analysed. The forecasts at the front, Dr. Gold stated, had generally been good. His figures proved that the effect of wind on projectiles is underrated, and that with certain wind directions and speeds it would be useless to send out aeroplanes and airships which could not return to their origin. Though Dr. Gold had much of interest to say on the results obtained, however, the general circulation in the atmosphere remains too complex a problem to admit of being summed up in a few sentences.

NOTES.

RAILWAY ELECTRIFICATION.

IT is difficult to exaggerate the importance to the nation of the work which lies before the committee recently appointed to report to the Minister of Transport on the question of railway electrification. This committee, which met on Monday last, is composed of Sir Alexander Kennedy (Chairman), Sir John Aspinall and Mr. A. R. Cooper, representing the London Electric Railways; Mr. Roger T. Smith, Mr. Philip Dawson, Sir Alexander Gibb, Mr. C. H. Merz, Sir Philip Nash, Sir John Snell and Sir Henry Thornton, representing the Railway Companies' Association, while Major Redman is Secretary. The task of the Committee is to consider and report as to whether any regulation should be made to ensure that future railway electrification schemes are carried out with due regard to the interchange of electric locomotives and rolling-stock, uniformity of equipment, and other matters, and to decide what matters should be dealt with by such regulations, if desirable. To find a system suitable for general application

under the widely varying conditions which exist in different parts of the country will be difficult enough, but even this will be easy in comparison with a third point with which the Committee has to deal, viz., as to whether it is desirable to alter existing electric lines, and if so, to what extent, so that they may form parts of a unified system. The Committee, however, is an exceedingly strong one, and one which appears to us to be well competent to find the best possible answers to the important questions involved. Its report is, therefore, awaited with considerable interest.

OIL *versus* COAL FOR SHIP PROPULSION.

There can be no question of the advance in popularity of oil as a fuel for ship propulsion, and this is accentuated by the difficulties arising from the reduced production of coal, its high price, and the probability that these two disabilities hitherto experienced with regard to oil will obtain with equal force in respect of coal. Following upon war experience, an increasingly large number of ships have been fitted with oil fuel, and an interesting comparison was made by Sir James McKechnie, K.B.E., at the launch of a new Cunarder from the Vickers' works at Barrow-in-Furness on Tuesday. The ship was named the Scythia, and the fact that it is forty-five years since a Cunarder bore the same name, led Sir James to make a comparison as to the fuel economy of ship propulsion since that time. He stated that in 1875 a hundred tons of cargo required the consumption of 17 lb. of coal to convey it 1 mile on its ocean voyage, whereas the new Scythia, travelling at the same speed as the old vessel, would only require about 4 lb. of coal or about 3 lb. of oil fuel if used in boilers. He contended that even geared turbines with oil fuel was but another stage, and not finality, in the evolution of the marine engines, and hoped soon to see the day when internal-combustion engines would be regarded by shipowners as capable of application to higher-powered vessels of the ocean type. The oil consumption for conveying 100 tons of cargo for a mile would then be only 1½ lb. of oil fuel. He added that "when one reflected on the millions of tons of cargo continuously in transit on all the seas, the saving which would be effected by the adoption of the internal-combustion engine would amount in a year to millions of tons of fuel. Apart altogether from the monetary advantage, there would result a better conservation of fuel, which is the main source of mechanical power." The Scythia has a length of 600 ft., a beam of 73 ft., and a depth of 45 ft. The gross tonnage is 21,000 tons, and accommodation is to be provided for 2,600 passengers. The double reduction geared turbines with which she is to be fitted are designed to generate 12,500 shaft horse-power, giving a speed of 16 knots. Amongst several notable features is the fact that the steering gear is of the electro-hydraulic type, and that the windlasses and capstans will be driven by the same power. A Sperry gyroscopic compass is to be installed.

RESTORATION OF PRE-WAR PRACTICES IN WORKSHOPS.

In a recent issue reference was made to the decision of Lord Sands, the Scottish Judge of Munitions Appeals, in the case of James Prentice against Messrs. Wm. McPhail and Sons. The terms of the judgment have now come to hand. During the war the firm introduced female labour on light core work, and they still retained three women on that work. They had not employed women on such work prior to the war, and had therefore departed from their own pre-war practice, and they were prosecuted for failure to restore their pre-war practice. They pleaded that there was a pre-war trade practice of employing female labour on such work, and that, therefore, although they had departed from their own practice by introducing women on the work, they had not departed from the trade practice. The Munitions Tribunal at Glasgow held that a trade practice within the meaning of Section 1 sub-section (1) of the Restoration of Pre-war Practices Act is the practice prevailing in the particular establishment in question and not the practice prevailing generally in a trade. The firm appealed, and Lord Sands reversed the Tribunal's judgment and sent the case back to the Tribunal in order that it might determine whether there is any rule, practice or custom obtaining in the brassfounding industry against the employment of women at light core work. The judgment, which states the legal position very clearly, is as follows: "Section 1 of the Restoration of Pre-war Practices Act, 1919, provides (1) Where, in any establishment to which this Act applies, any rule, practice or custom obtaining before the war in any industry or branch of an industry (hereinafter referred to as a trade practice) has, during and in consequence of the present war, been departed from, the owner of that establishment shall be under an obligation, at the expiration of two months from the passing of this Act, to restore or permit the restoration of the trade practice so previously obtaining. . . . . This provision, it will be observed, deals with something which has been departed from, and which has to be restored. The question which here arises is, 'What is that something?' It is not any rule, practice or custom obtaining before the war in the particular establishment, but it is any rule, practice or custom obtaining before the war in any industry or branch of an industry. In order, therefore, that the provision may be called into operation it is necessary to show that a rule, practice or custom obtaining in the industry, or a branch of the industry, has been departed from. No other construction can, I think, be reached, unless the words 'in any industry or branch of an industry' be read out of the section, and this is an impossible mode of construction. I am unable to read the section as if it ran, 'Where, in any establishment to which this Act applies, any rule, practice or custom obtaining before the war in such establishment has, &c., &c.' If it were permissible to consider the presumed intention of the Act, as it might be if the expression were ambiguous, this would not, in my view, help the respondents. I apprehend it was the intention of the Act to prevent the employer from continuing a practice which, if there had been no war, would have been vetoed by general trade rule and could not have been introduced without a labour dispute. I do not think it was intended to compel the employer to discontinue a practice which is consistent with trade rules, and which he might have introduced if there had been no war without incurring any trade veto."

ORGANISATION AT THE FORD MOTOR WORKS.

In a general way engineers have an idea of the methods adopted at the Ford Motor Company's works to secure the phenomenal output which they now have. A few details of these systems were given in a paper read by Mr. Thomas Gorst before the Manchester Association of Engineers on March 13. It will be readily understood that it must have been difficult for the author to compress into a few pages even the main features of this huge organisation, with all its extreme specialisation, and the paper suffers from this, viewed as a contribution to technical knowledge. It is interesting to note that in the tool department alone at Detroit over 3,000 men are employed. The whole organisation is planned to keep a steady stream of material and parts flowing through the shops, and a check is provided at every point on progress. At critical points of manufacture a three-days' supply of the part is stocked to tide over emergencies which might interfere with the regular flow and so cause the whole organisation to break down. Hourly results are furnished to the workshop superintendent. The arrangement of the machines, &c., is fixed by the character of the operations, which often involve furnaces, &c., being in their proper place in the line. Chutes and conveyors of endless chain cradles handle practically all the material down the shops. Interdepartmental transport is effected by tractor and chassis trucks. The work is assembled on the unit system, the supply of all parts being carefully synchronised, and finally all units synchronised to produce the finished car. The unit moves forward progressively and operations are carried out on it in regular sequence. In assembling the motor there are 60 different operations, each with subdivisions. Before the progressive system was introduced 1,100 men turned out 1,000 engines a day. After the adoption of the conveyor method, and the adoption of the profit-sharing scheme, 1,400 men finished over 3,000 motors daily. The final assembly, as is known, is done on a conveyor, the various parts being added at determined points from sub-assembly supply stations. When all has been added the car has arrived at the testing station, where it is run on to a floor in which there are four V-grooved wheels below the floor. The rear wheels of the car are dropped between these and they are driven forward. The clutch is let in and the engine is driven by this means. To switch-on and make adjustments are all that is needed for the motor to start upon its own. After adjustment the car is ejected from the rollers by a pneumatic ram, and is driven off for a run under observation. The conveyor system is adopted in the foundry as well. This department works 24 hours a day. The moulders work alongside a conveyor moving at 12 ft. per minute. The moulding sand is supplied from hoppers overhead discharging on to the moulding machine. One moulder makes each part of the mould, which is assembled and moved on to the conveyor, by which it is carried to the point where the metal is poured. While the mould is being poured it continues to move forward. At the end of the conveyor the casting is thrown out to cool, the flasks are returned to the moulders by conveyor, and the sand drops through a grating in the floor to be returned to the hoppers subsequently by conveyor. At one time it was usual to engage about 40,000 men during the year to maintain a working force of 10,000. For this reason welfare methods and profit-sharing were introduced, with the result that with a working force of 41,000 only about 7,500 now relinquish the service of the company during the year. A good deal has been written about the work of Dr. Mead, the company's chief medical officer, and the training of disabled ex-service men. There are now 10,000 men disabled to a greater or less degree in the works all doing work which is economically justified. This has been attained by carefully selecting the job to fit the case of disablement, and the results are as commendable for patriotic reasons as they have proved satisfactory to the company.

THE INSTITUTION OF NAVAL ARCHITECTS.

THE spring meeting of the Institution of Naval Architects commenced on Wednesday at 11.30 a.m., at the Royal Society of Arts, Adelphi, the Earl of Durham, President, occupying the chair.

REPORT OF THE COUNCIL.

The proceedings opened with the presentation of the council's report, which stated that 288 members of all classes had been admitted to the Institution during the preceding twelve months. The financial position was satisfactory, but the margin of receipts over expenditure was reduced. Owing to the liberality of several firms, 15 scholarship funds were administered by the Institution. It was hoped that further development in this direction would ultimately enable one scholarship in naval architecture, and one in marine engineering to be established at each university centre. The Elgar scholarship had been awarded to Mr. W. G. Green; the Cammell Laird to Mr. H. T. R. Biles, and the Parsons scholarship to Mr. W. G. Simmons. The Earl of Durham prize had been awarded to Mr. W. G. A. Perring.

The council was of the opinion that the Bill promoted by the Institution of Civil Engineers for the registration of Civil Engineers would be, in its present form, injurious to the status and interests of Naval Architects and marine Engineers, and it was decided to oppose it. The council has under consideration the question of examinations in addition to practical training as qualification for membership of the Institution. A report was recently issued dealing with the training of apprentices. The Marine Engineering Committee had obtained the unification of rules governing the design and construction of boilers and their accessories; these have been approved by the Board of Trade, Lloyd's Register, the British Corporation, and Bureau Veritas. The Institution had been represented on the Advisory Committee of the Board of Trade, the British Engineering Standards

Association, Imperial College of Science, Technical Committee Lloyd's Register, Conjoint Board of Scientific Societies, the National Physical Laboratory and the Froude National Tank. It is proposed to hold a summer meeting in Liverpool on July 6 to 8 this year.

The annual gold medal for 1919 had been awarded to Dr. J. Montgomerie for his paper on "Further Experiments on Stress Determination in Flat Steel Plates." The annual premium had been granted to Mr. C. L R. Campbell, R.C.N.C., for his paper on "The Development of Airship Construction."

Election of Officers.

It was then announced that the following had been elected to the Council: As Members of Council: Professor T. B. Abell; Mr. A. J. Campbell; Mr. M. E. Denny, C.B.E.; Mr. J. Hamilton Gibson, O.B.E.; Mr. D. B. Morrison; Mr. R. L. Scott; Mr. J. Smith; Sir J. E. Thornycroft, K.B.E.; the Right Hon. Lord Weir. As Associate Members of Council: Sir Kenneth Anderson, Bart., K.C.M.G.; Sir Alfred Booth, Bart.; Sir A. K. Wilson, V.C., O.M., G.C.B.

Civil Engineers' Registration Bill.

Sir J. Fortescue Flannery then rose to refer to the above Bill now before the House of Commons. He wished to emphasise the importance of the question from the point of view of nearly every member of the Institution who was practising in the profession. It did not so directly affect the members who were shipbuilders or contracting engineers, but it did affect vitally, and at the root of their livelihood, all engaged in professional work. The Bill proposed that unless a man were registered under the *ægis*, selection and control of the Institution of Civil Engineers he could not legally practice as an engineer. There was no desire to prevent the Council of the Institution of Civil Engineers from proposing legalisation and registration of their members; but the Institution of Naval Architects desired, and was legitimately entitled to desire, that an institution which, like theirs, had been in existence for half-a-century, should not be deprived of the right of selecting and registering its own members. That was the essence of the matter. The members of the Institution of Naval Architects did not think that they should have to go to another institution to be legalised in the practice of their profession. He hoped his remarks would emphasise the vital importance of the question, and that each member would do something in the matter; for example, by writing to his Member of Parliament, or in some other way calling attention to the matter, and arranging that justice be done to an old and time-honoured Institution.

Presidential Address.

The Earl of Durham then delivered his presidential address, which he opened by referring to the prosperity of the Institution. During the past four or five years, in spite of the great war, this had been steadily maintained, notwithstanding that it had been deprived of the assistance of many of its important members, who had been giving other service to their country. Conditions were now returning to the normal, and in the present and succeeding years there was every prospect that the Institution would be able to hold its own. Last year the Marquis of Bristol had mentioned the shipbuilding efforts in the yards on the other side of the Atlantic to meet the great danger to our shipping industry from the submarine warfare. The German menace, however, was now over, and was either swept from the seas or was lying beneath the waves at Scapa Flow. British industry and enterprise would help us once more to attain our former position of supremacy, but one thing was absolutely essential, namely, the commonsense of the British nation, which so far had never failed us in our history. It was, however, midsummer madness to assume that we could ignore all the tenets of political economy and all the hard facts of civilisation; if we kept on such a course we should no longer be a wealthy or a progressive nation. High cost of living was a cause of anxiety and unrest, but it was folly to suppose that high wages would counteract high prices unless there were increased production and unless the cost of that production were kept within proper limits. During the next few years, in shipbuilding as in other industries, willing purchasers would be found for ships which could be offered at reasonable prices. But high wages and diminished output would drive the old customers to foreign markets. There were some labour leaders who seemed to think that they could get better conditions even if this country had neither commerce nor exports. The hibernating bear could do without food because it lived on its own fat; the British lion, however, would very quickly starve. Unrest and suffering were the usual sequels of a great war, but the remedy was not in revolution. He was convinced that the great majority of Englishmen would firmly repress any attempt at revolution. "Direct action" was a phrase rather less offensive than "blackmail" or "highway robbery," but if it were intended to resort to the latter under another name the country would have none of it. What labour suffered from was lack of time and opportunity for careful and calm consideration of difficult problems, and from mischievous propaganda. The men would greatly benefit by better educational conditions, and he would here like to refer to the education and training of apprentices in shipbuilding and marine engineering. If the nation were to regain its past pre-eminence in industry, effort would have to be even greater than in the past. This effort would have to be sustained by the young men now going through their apprenticeship, and those coming behind them. If such were to succeed against commercial adversaries their intellectual weapons would have to be improved. A strong committee of the Institution had drawn up a scheme for the best means of improving the education and training of apprentices. That scheme was necessarily on broad lines, leaving the details to be worked out as best suited the various firms and localities. In this connection the speaker suggested that, after a reasonable time had elapsed, a paper should be read, or a conference held, to show what progress had been made. Of course, in some cases obstacles would be raised by the trade unions, but such, it was hoped, would be overcome, and the trade unions themselves might be brought to see that their own prosperity was bound up with that of industrial progress. If it could be shown that industrial progress depended on the education and training of apprentices, either such obstacles would be removed or alternative methods adopted to secure the same end.

Lord Durham also referred to the scholarships in naval architecture and marine engineering which had been successfully established, owing to the generosity of some of the principal shipbuilding and marine engineering firms, as an inducement to apprentices to devote more energy to the pursuit of knowledge. A selective method was to be adopted in order to bring forward those from whom great things might be looked for, not only for the benefit of their careers, but for the benefit of the industry in which they were engaged. It was generally desired that apprentices in every trade in the country should be encouraged, and that every young man, whatever his position, should be given the fullest opportunity of advancing himself in life. The number of candidates had not been as large as was hoped, but perhaps when greater publicity had made these scholarships more widely known, more encouragement would be afforded to those under whose charge the apprentices were working.

He would ask the members present earnestly to further in every way they could the education of the young apprentice, and he concluded with the expression of a hope that, in these difficult and parlous times, every single member of the Institution would remember that he, or she, could, by their individual example and sympathy, promote the welfare and prosperity of the country.

H.M.S. Hood.

The first paper to be taken was one by Sir Eustace d'Eyncourt entitled "H.M.S. Hood." The paper, which we reprint on page 423, was read by its author. In the course of his reading Sir Eustace stated that the Hood was now on her trials, and that the estimated figures given in the paper had been exceeded. She had steamed 32·07 knots, the engines giving 150,000 h.p., and the propeller revolutions being 206. When fully laden she had steamed 31·9 knots, so that the legend speed of the original design had practically been secured with the additional armament as built.

Admiral the Right Hon. Viscount Jellicoe opened the discussion. He congratulated Sir Eustace d'Eyncourt both on his paper and on the completion of the finest fighting ship in the world. Sir Eustace had shown great courage in the adoption of the bulge in the early part of the war, and the Navy owed much to him and to the constructional department of the Admiralty for what had been done in connection with it. There were one or two points on which he would like to ask questions. In the United States recently he had seen models of the proposed new battle cruisers and noted that the bulge was carried right up to the bows. He was told that tank experiments proved this construction to give improved speed as compared with starting the bulge further aft and would ask Sir Eustace's opinion on the matter. Another question was what weight was saved in the Hood by the adoption of small tube boilers? In 1910, when he was Controller of the Navy, Sir Charles Parsons had advocated small tube boilers, and he, Lord Jellicoe, had asked the opinion of many shipyard people on the matter but had received no encouragement. Finally, on the question of the retention of the capital ship, he thought all interested in ship construction would have read the recent report of the Board of Admiralty with relief. He thought in agreement with the report that the day of the capital ship was not yet finished.

Constructor-commander E. S. Land, of the United States Navy, the next speaker, said that the Hood represented a sort of climax in warship design. If he might criticise he would say that he would have liked a little more deck armour and a little less side armour, also a little more protection in the turret tops. The gun elevation of 30 deg. he also thought might usefully be more. As a minor point, he was somewhat amused by the number of different types of engine arranged for driving the dynamos. On the other hand, he thought the sloping of the armour and the arrangement of the conning towers was excellent, as also the arrangements for ventilation. He was glad to see the abandonment of the hand steering gear. This should have been done long ago. He thought perhaps the most flattering thing which could be said about the Hood was that it was difficult to say if she was a battle cruiser or a battleship. As imitation was the sincerest form of flattery, he would conclude by saying that the Americans were copying the Hood.

Sir Philip Watts was the next contributor to the discussion, his remarks being read by Sir William Smith. He first referred to the small tube boiler which, he stated, he had advocated for years. If the Tiger had been fitted with such boilers she would have had the speed and the protection of the Hood. Turning to the question of underwater protection, Sir Philip said that for the early Dreadnoughts Lord Kelvin had proposed a method of protection with outer compartments but Lord Fisher ruled it out as the weight involved was too great. The method of outer water compartments was all right when space was available, and in early designs of the Tiger such spaces 6 ft. to 8 ft. wide were provided. The method was good against the cruising effect of a torpedo as it gave a good space for it to explode itself in. The only real difference between the Hood and earlier ships was that the long bulkhead was not vertical. The idea of the bulge appeared to be to keep the explosion outside the ship, but if it was sufficient now it would not be sufficient for the larger torpedoes which were already being made. The essential features of the bulge existed in all modern ships and the protection it gave was not the same as that given by a torpedo net. The bulge was part of his ship, but he thought it would be possible to make a rigid shield to be lowered from the ship to deflect or explode a torpedo. There was a point in connection with the lower armoured deck of the Hood which he would also like to refer to. This deck came flush at its edges with the lower edge of the main side armour. A projectile from above penetrating the deck would probably reach a vital part of the ship. If the pro-

tection were divided between two decks a projectile arriving above the level of the side armour and penetrating the upper of the two protected decks would probably explode between them and not reach a vital part.

Mr. C. E. Stromeyer said he would like to ask if the Hood would tilt if she were hit by several torpedoes. The question of the protection of vital parts was one of the chief points of the ship, and he would like to compare her from this point of view with the Royal Sovereign. Considering the main structure of each ship as a box girder, one had the side plating forming the main vertical members of the girder in the Hood. Outside these plates there was the bulge, which did not materially contribute to the strength of the girder. In the Royal Sovereign the heavy plating forming the main vertical members of the girder was inside the hull, with a compartment between it and the outer skin corresponding to the bulge. The result of the Hood construction was that the side plating rested on much longer cross beams than the corresponding plating in the Royal Sovereign, with consequently a weaker form of construction. He had given some attention to the protection of ships against torpedo attack in 1912, and as a result of experiments decided that the best construction was to have the thick plate inside the thin one, as in the Royal Sovereign, and not outside as in the Hood. If the outer plate were thick and it were destroyed, there was a fair chance that flying fragments might go through the thin inner plate. With the thin plate outside, this was less likely to happen. The second form of construction had been adopted in the Royal Sovereign. He was sorry bulges had been introduced, as they did not make for strength.

Captain Chatfield said that as a member of the Admiralty staff he would like to add his tribute to the work which had been done by Sir Eustace d'Eyncourt. It must be remembered that although the Hood was a war product, she was not the product of all our war experience. She was originally designed before the Battle of Jutland, and if she was to be criticised should be criticised from the point of view of her design. All ships were compromises, and one had to consider for what purposes a ship was designed. The question of speed had been emphasised as being a great thing in warfare. It was said that speed gave one the choice of range. It was doubtful, however, if this was true. In ninety-nine cases out of one hundred the weather determined the range, and once inside that range a ship with plenty of speed but not too much protection might not be very comfortable. We had sometimes built ships with too much of one thing and not enough of another, but he thought it was now better realised that compromise was necessary. Naval officers must take a fair share in the responsibility for design. If a design was a failure it was quite possible that it was due to naval officers not saying, or not quite knowing, what they wanted.

Mr. Archibald Hurd, the last speaker in the discussion, said the real naval lessons of the war were known only to naval officers, and the determination of future design could not be safely undertaken until the results of those lessons had had time to crystallise. The Hood was the finest ship which had been designed since the capital ship arrived, and we were on the path of great developments. There was danger in rushing ahead before all we had learned had been appreciated, and in deciding for instance that the day of the capital ship was dead. One should not be too ready to drop the old to seize the new.

Sir Eustace d'Eyncourt, replying to the discussion, thanked the various speakers who had spoken kindly about the Hood. He, for his part, would like to pay tribute to his staff, and particularly to Mr. Attwood, without whose splendid support the work could not have been done. In reference to Lord Jellicoe's question about the carrying of the bulge right forward, he thought perhaps we should re-arrange our ideas about the bulge. The bulge was part of the ship and was not something stuck on. The name was, perhaps, a bad one, and blister was perhaps worse. The carrying of the bulge forward could, of course, be done, but such protection in that part was not so important. If some forward compartment was broken into, the effect in general would not be so serious. The "Achilles heel" of all ships was often in the neighbourhood of the rudder and propellers, but such positions had usually escaped damage in the war for some reason.

In connection with the weight saved by employing small tube boilers, the best way of stating the matter was that one obtained 30 per cent. more power with the same weight. With such boilers on the Repulse and Renown one could almost have added another turret. In reply to Commander Land he would say that since the ship was first designed the proportion of armour in the decks had been increased. There was now good protection. He was glad the Commander liked the turrets. They were expensive articles, and weighing 600 tons, were difficult to deal with. Sir Philip Watts' criticism he had not time fully to deal with, but could not agree that the bulge was not an advance on which we had before. Its advantage was that an explosion could take place upwards and outside the ship proper. It saved the integrity of the inner bulkhead. He thought it very desirable to keep an explosion away from the upper works of the ship if possible. It had the great advantage over any form of loose shield, that it was part of the ship and did not demand a lot of care and attention from the officers.

GERMAN SUBMARINES.

The second paper taken was one entitled "German Submarines," the author being Mr. A. W. Johns, R.C.N.C. This paper is reprinted elsewhere in this issue of ENGINEERING. The first speaker was Rear-Admiral D. L. Dent, who is now in charge of the submarine work. He stated that he was not properly a submarine officer, and had only recently taken on his present duties, but had been asked to speak by Admiral Sir R. Hall, who was formerly in charge of the submarine work. His remarks were rather of a personal than a technical character. The Germans built their submarines for a notably different purpose from that which we had in view in designing ours. Theirs were built for the purpose of attacking trading vessels, and, therefore, no real comparison was possible with our craft. There appeared to be a tendency to underrate the work done by submarines. It had been stated that with high speed a ship was practically immune from torpedo attack. He considered that a dangerous theory to rely on. The Germans concentrated their attack on our trading vessels, leaving our war vessels practically alone. During the war we had built the largest and the fastest and the heaviest torpedo-armed submarines in existence. Here the work was carried on as merely one portion of a large output. In Germany, on the other hand, the building of submarines constituted the main national effort. The results we had achieved could not have been attained without the efforts of Mr. Johns. He considered the proper relation between the designer and user most essential to the success of a ship. To get good results both had to work together. Sympathy must also extend to the building yards. This sympathy existed in a marked degree between the author and the officers of the submarine service. Proof of the confidence the officers had in Mr. Johns was given by the way they took to sea the boats built under war conditions with a minimum of testing.

Sir Eustace D'Eyncourt paid a tribute to the exhaustive character of Mr. Johns' paper, which enabled them to draw valuable conclusions. He thought the Germans had the advantage over us in the use of the large cylinder. They had adopted 300 h.p. per cylinder, while we had, for certain reasons, confined ourselves to the standard 100 h.p. per cylinder. This was mainly due to the need of rapid construction over here; but it meant that in one class we had 36 cylinders to an engine, while the corresponding German type of boat had only 12. In spite of that, however, we had produced the faster boat. It was most satisfactory to hear that the users were pleased with the boats they had to work, and in which they had to take such risks. He thought it most satisfactory that so many officers who had fought in the war had come to the meeting of the Institution. It was most valuable to have their views now it was possible to air them, and such exchange of views made great progress possible.

Commander E. Land (United States Navy), said the author might have made his paper more critical. The Germans had waited while the British, French and other navies had gone ahead in this matter, and then when the war came they had begged, borrowed and stolen ideas from everybody. They had, as a result, obtained a great deal of credit which was not rightly theirs. He thought the British boats better than the German in practically all essential features. He had no quarrel with the advocates of the capital ship, but he thought the submarine had not been given a real chance. It had done great things in the war. He agreed with what others had said with regard to Mr. Johns. The author was regarded as a real friend by submarine officers. Similar sentiments were held in all the yards he had visited, and he thought much more credit should be given to the author and his work in connection with the British Navy than so far had been accorded.

The meeting then adjourned.

NET EXPERIMENTS IN CONNECTION WITH SUBMARINE WARFARE.

On reassembling after the luncheon interval a paper was read by Mr. G. S. Baker entitled "Model Experiments in Connection with Submarine Warfare." This paper will be reprinted in a subsequent issue of ENGINEERING. It dealt in a very interesting manner with a series of experiments representing submarine attacks on nets, carried out at the Experimental Tank, Teddington, to the order of the Boom Trial Committee. The experiments consisted of tests made with a model representing a modified E class submarine, one-eighteenth full size. The nets and floats were worked out to scale, and records were taken of the tension put on the jackstays under various conditions of attack, and on the effect on the vessel in attacking at the surface and at various depths below the surface, directly at right angles to the net or partly sideways. Indicator nets were also the subject of experiment, and a great deal of work had been done at the Tank in connection with a satisfactory towing float for these. Mr. Baker supplemented his paper by some interesting lantern slides which were parts of cinematograph films showing the behaviour of a submarine on striking a defence net. These views showed the net deflected by the impact, and the submarine being brought to the surface till its bows were quite out of water and it was inclined upwards at between 40 deg. and 50 deg.

The only speaker on this paper was Sir Eustace d'Eyncourt, who said he hardly felt competent to say much, but he had the privilege of seeing some of the experiments and of conferring with the author in regard to the work. He considered it one of the most interesting papers they had had; it gave an insight into the interesting work done at the National Physical Laboratory. It was hardly possible for anyone to appreciate that work without having seen something of it and the difficulties involved, difficulties, for instance, with regard to fixing the scale for the wire of the nets, and other similar points. The results obtained had been most useful to them at the Admiralty in enabling them to work out effective means of combatting the submarine. That was only one of a number of researches carried out at the National Physical Laboratory for the Admiralty, and he was glad of the opportunity of testifying to the help they had been in defeating the enemy. The paper showed how carefully the author had gone into the minutest detail, and he felt he could hardly sufficiently express his admiration for the work.

The meeting then adjourned till Thursday morning; these further proceedings will be dealt with in our issue of next week.

THE ANNUAL DINNER.

The annual dinner was held on the evening of Wednesday, at the Connaught Rooms, Great Queen-street. In point of attendance this was the most successful function of its kind ever held by the Institution, there being about 480 members and guests present. The chair was taken by the president, the Earl of Durham, who, after giving the usual loyal toasts, proposed the "Naval and Military Forces of the Empire." Rear-Admiral Sir William Nicholson, the Third Sea Lord, responded. An interesting feature of the evening was the presentation of a loving cup by the Institution to

Monsieur L. E. Bertin, President of the Association Technique Maritime. In making the presentation the Earl of Durham referred in apt terms to the friendship and common work which during recent years had drawn France and Britain closer together. The toast of the "Mercantile Marine" was proposed by Sir Thomas Mackenzie, High Commissioner for New Zealand, and responded to by Sir Joseph Maclay, Controller of Shipping. The final toast was "The Chairman," proposed by Mr. Alexander Richardson, M.P. The president's reply was the final item in an enjoyable evening.

(To be continued.)

THE LATE MR. JAMES GAYLEY.

WE regret to have to announce the death which occurred on February 25 last of Mr. James Gayley, first Vice-President of the United States Steel Corporation. He was born at Lockhaven, Pa., on October 11, 1855, and in 1876 began his professional career as a chemist at the Crane Iron Company, Catasauqua, Pa. Mr. Gayley then took up an appointment as Superintendent to the Moussouri Furnace Company, a position which he resigned later to undertake the management of the blast furnaces of the E. and G. Brooke Iron Company, Birdsboro, Pa. In 1885 he took charge of the furnaces of the Edgar Thomson Steel Works, at Braddock, Pa., which were owned by Carnegie Bros. and Company, and which, subsequently, became the Carnegie Steel Company. He was afterwards manager of the entire Edgar Thomson plant, and in 1897 he was given the position of Managing Director of the Carnegie Steel Company. While at the Edgar Thomson Works he was the first to instal charging bins for the raw materials at the blast furnaces, and he also put down the first compound condensing engine for supplying air blast to a furnace. At the ore docks of the Carnegie Steel Company, on Lake Erie, he built the first mechanical ore unloader, and designed a vessel adapted to the use of such unloaders. Mr. Gayley made many important contributions to the progress of metallurgical industry, and among some of his inventions may be mentioned the bronze cooling plate for blast furnace walls and the auxiliary stand for holding the ladle while the Bessemer heat is being poured.

He also introduced the "dry air blast," for which he was well known on the Continent. This latter invention was reckoned as probably the most important since Neilson's application of the hot blast in its relation to the reduction of iron ores. One of the chief causes of variations in the working of a blast furnace and of the inequality in its product is found in the greater or less percentage of moisture in the blast, but this had been accepted as inevitable until Mr. Gayley conceived the idea of drying the air by removing the moisture from it by refrigeration, the dried air current then passing to the hot blast stoves, and from them into the furnaces. The result is an important fuel economy with uniformity of furnace product, the gain being about 20 per cent. At the meeting of the Iron and Steel Institute in America in 1904 Mr. Gayley read a paper on the "Application of Dry Air Blast to the Manufacture of Iron" (see ENGINEERING, vol. lxxviii, page 661). He also read before the American Institute of Mining and Metallurgical Engineers papers on the "Development of American Blast Furnaces, with Special Reference to Large Yields," and "The Preservation of the Hearth and Bosh Walls of the Blast Furnace." In the session 1904 to 1906 he was President of the American Institute of Mining and Metallurgy; he was a member of the Iron and Steel Institute since 1888. When the United States Steel Corporation was formed in 1901, Mr. Gayley was made first Vice-President, a position which he held until 1909. In 1912 the University of Pennsylvania and Lehigh University conferred upon him the honorary degree of Doctor of Science; in 1906 he was awarded the Elliott Cresson medal, and in 1913 the Perkin medal by the Franklin Institute of Philadelphia.

THE PHYSICAL SOCIETY OF LONDON.

AT the meeting held on March 12, 1920, at the Imperial College of Science, Professor W. H. Bragg, F.R.S., president, in the chair, a paper on "*Absorption of Gases in the Electric Discharge Tube*" was read by Mr. F. H. Newman.

The paper describes a method of showing that absorption of nitrogen takes place in the discharge tube when sodium and potassium are used as the electrodes. The amount of gas absorbed for different quantities of electricity passing in the circuit is measured and is less than that absorbed by the sodium-potassium alloy. It shows also that when the alloy is used the amount of gas absorbed increases with temperature.

Dr. Beattie referred to the bearing of the phenomena on photo-electric cells. He asked if it was possible to get such complete absorption as to give an X-ray vacuum, or if there was a dissociation pressure of the gas in equilibrium with the metal. The fact that the alloy absorbed more than either metal separately was possibly a surface tension phenomenon. If a compound was formed of which the surface tension was greater than that of the alloy, it would be drawn inwards, leaving a fresh surface of the uncontaminated alloy in contact with the gas. He had found that when a discharge passed in vacuum between iron electrodes a good deal of hydrogen was emitted. If the discharge was stopped this was re-absorbed although had the discharge been continued the emission would have gone on as before.

Professor Fortescue said the phenomena was probably the result of several different effects. For instance, if the volatilised films had not been at atmospheric pressure after volatilisation, the fact that they absorbed while the non-volatilised metals did not, might be accounted for by the latter having retained gas previously absorbed while exposed to the atmosphere, while the former presented a fresh uncontaminated surface. It was further possible that the thickness of the sodium and potassium layers affected the results. As regards the anode and cathode effects, will this not depend on the relation between the numbers of positive and negative ions present? The author says there is no time effect. Does he mean by this that the absorption will go on, say, for 50 or 60 hours at a constant rate?

Mr. F. J. Harlow pointed out that the films of sodium and potassium were redistilled on silver. Might there not be alloys formed under these circumstances, the alloys and not the metals themselves, possessing the absorptive powers? Had the author used a lime cathode? With this it was possible to get a very steady discharge from the lighting voltage.

Mr. B. F. Dudding thought we were here dealing with problems which Langmuir and others had worked out at some length. Some recent work of Dr. Norman Campbell showed that, with suitable discharge conditions, compounds of almost any two elements could be formed. The essential thing was to remove the products of the reaction in some way so as to keep a clean surface.

Mr. Newman, in reply, said that it was not possible to get a very high vacuum with hydrogen. Although it was absorbed by the alloy it was impossible to get rid of the last traces. The surface of the alloy must be very clean. When the discharge is in nitrogen the surface keeps clean, the scum formed breaking up and going to the sides of the tube, but with hydrogen a black scum forms which requires to be mechanically removed by shaking the tube. As regards the constancy of the rate of absorption, he could not give actual figures, but the rate certainly did not diminish for a very long time. He agreed that it would be difficult to prove that the sodium and potassium films had not alloyed with the silver. He had not tried a lime cathode, but had got very steady discharges by using the type of Wehnelt interrupter, which he had recently shown to the Society.

A paper on "*A Directional Hot-Wire Anemometer*," was read by Mr. J. S. G. Thomas.

The instrument consists of two fine platinum wires mounted close together, and forming two of the arms of a Wheatstone bridge. These are heated by the current in the bridge. When a stream of gas moves in a direction perpendicular to the wires but parallel to the plane containing them, the leading wire is cooled, while the second wire, being shielded by the first, is not cooled as much, and may actually be heated on account of the air flowing past it being warmed by the first wire. A deflection of the galvanometer is obtained, therefore, which is reversed if the flow of gas is in the reverse direction. The instrument is much more sensitive than the non-directional hot-wire anemometer.

Dr. Ezer Griffiths said he had been working with hot-wire anemometers recently, but they required somewhat complicated gear. It is assumed in working out the theory that the flow of gas is parallel to the axis of the tube. What happens if this is not so owing to the proximity of bends?

Dr. Tucker said he had used a hot-wire anemometer for impulsive and alternating flows. But the hot-wire inevitably produces its own direct current due to convection. He had found the curious result that the sensitivity for alternating currents could be increased many times by increasing the strength of the direct current to which the wire was exposed. Had the author attempted to increase the sensitivity by reducing the diameter of the wires? The sensitivity rose very rapidly as the diameter was reduced.

Dr. E. H. Rayner asked if experiments had been made with different dimensions to see if the range of usefulness could be increased. He thought the velocities in gas mains would usually be much greater than 4 cm. per second, which seemed to be about the maximum useful range with the present instrument.

Mr. F. E. Smith said he was not convinced by the author's explanation of the first wire being further cooled, due to the proximity of the second hotter wire. He suggested a simple experiment to prove whether or not this cooling actually took place.

Dr. Borns asked if all the experiments had been in coal gas.

Professor Rankine asked if any difficulties arose due to the wires not remaining in the plane parallel to the flow. One would expect sagging to occur, and the two wires would not necessarily bulge in the same direction.

Dr. D. Owen suggested that there might be some advantage in this respect if grids were used instead of wires.

Dr. L. Hopwood said the author was to be congratulated in finding a directional instrument which was more sensitive than a non-directional one. Direct measurements could be made on the convection current effects by using a vertical flow. In one direction the convection currents would assist the flow, and in the other would be against it.

Dr. T. Barratt (communicated): I have read Mr. Thomas's interesting paper with much pleasure. His explanations of the more or less intricate phenomena involved are convincing and simple. In one particular, however, the facts can be explained more simply as well as more accurately. Radiation from thin wires, even at moderately high temperatures, forms a very small percentage of the total heat lost. In the case of Mr. Thomas's anemometer wires, this percentage is probably less than 5, and certainly less than 10 if the wire is "bare"—*i.e.*, slightly soiled by exposure to air, &c. That is to say, nearly all the heat is lost by convection. An explanation of the observed facts can be made, however, without any assumption of radiation at all. Assuming that nearly all the loss of heat is due to convection, "free" or "forced," the air reaching b from the direction of a is considerably warmer than the rest of the gas. Hence the convection from b (which strictly obeys Newton's first power law) is considerably reduced, resulting in a higher temperature for the wire b. At higher velocities of the cooling fluid the air from a reaching b is not so warm, so that b is cooled more than at low velocities. The remaining explanations can follow on the same line of reasoning.

The author, in reply, said that as regards disturbed stream lines, King's investigations showed that the turbulent condition could be better investigated with hot-wire anemometers than by other types. In the gas works the instruments are fitted far from bends. One important point was that owing to the proximity of the wires the zero reading is much more constant than with the ordinary non-directional type. With regard to the points about convection currents mentioned by Messrs. Tucker and Hopwood, experiments had been made with vertical currents. He had tried the experiment suggested by Mr. F. E. Smith, and had verified the fall of temperature. He had used currents of air, carbon dioxide, oxygen, hydrogen and other gases. With hydrogen, methane, &c., the instrument with bare wires cannot be used at all, but the wires can be coated with glass without reducing the sensitiveness. It is this type that is used in the works. The wires getting out of line was certainly a difficulty, but he was getting over this by mounting them in such a way that they would always be kept taut. If time permitted he would try a grid arrangement as suggested by Dr. Owen. In reply to Dr. Rayner, he was attempting to develop the instrument for higher velocities.

Dr. Hans Pettersson exhibited and described a new microbalance.

This instrument, which is sensitive to a few millionths of a milligram, is constructed entirely of quartz. Its special feature is that no knife edge is employed, the beam being suspended by two very fine quartz fibres.

The exhibitor gave an account of some interesting physical problems, which the instrument was being employed or about to be employed to solve.

ROYAL METEOROLOGICAL SOCIETY.

THE usual March lecture of this society was delivered on Wednesday, the 17th inst., at the rooms of the Royal Astronomical Society, Burlington House, by Captain C. K. M. Douglas, F.R.Met.Soc., the subject being "*Clouds as Seen from an Aeroplane.*" The president of the society, Mr. R. H. Hooker, M.A., was in the chair.

A large number of photographs of clouds taken from an aeroplane were shown on the screen, nearly all of which were taken by the lecturer while flying in co-operation with the Meteorological Section, R.E., in France, in 1918 and 1919. The primary object of the flights was to obtain the temperature in the upper air for the artillery and for forecasting, and advantage was taken of the opportunity to study cloud structure and its relation to the upper air temperature and humidity, and to the general meteorological conditions. The observations were made at Berck, on the French coast, 20 miles south of Boulogne, which lies close to the most important aerial routes. The photographs showed a large variety of cloud forms, and also some changes which took place in short periods. A number of the photographs showed thunderclouds. Thunderstorms are caused by powerful ascending currents, and the tops of the clouds grow up to a great height, frequently exceeding 20,000 ft. It is almost impossible for an aeroplane to climb above them, but it is nearly always possible to dodge them. Sometimes the tops of the thunder clouds stand out boldly from the lower clouds, and the pilot of an aeroplane who climbs up to about 8,000 ft. and flies above the lower clouds can see the thunder clouds a long way off and fly round them. Frequently, when the weather is overcast and gloomy there is brilliant sunshine within 1 mile or 2 miles of the ground, and the clouds viewed from above present a splendid spectacle. With the development of civil aviation, increasing opportunities of viewing cloud scenery will present themselves.

OVERSEAS TOURING EXHIBITION.—The Department of Overseas Trade proposes to organise a number of touring exhibitions of British manufactured goods to the principal commercial centres of the British Dominions, South America, the Far East and the United States. A pamphlet containing full particulars may be obtained from the Department, 35, Old Queen-street, S.W. 1.

ROUMANIAN AND DANISH RAILWAYS REQUIREMENTS.—The Department of Overseas Trade, 4, Queen Anne's Gate Buildings, Old Queen-street, S.W. 1, has received information concerning the requirements of the Roumanian Railways in locomotives and passenger carriages. They also require a 50-ton crane. The Danish Railways are in the market for large quantities of railway bolts, spikes, clips, &c.

THE TRAINING OF NAVAL ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—In your article in last week's issue, on the Naval Estimates, you magnanimously avoided the "I told you so" attitude with reference to what appears in the First Lord's statement, now issued as a White Paper. In this document is foreshadowed a complete reversal of the policy, hitherto in vogue, for the training of naval engineers, and it relegates to the "scrap heap" nearly all that remains of the Selborne scheme which came into operation in 1902.

As is well-known to all your middle-aged readers, the Selborne scheme superseded the Keyham system of training naval engineer officers, and set up in its place the "observational engineer officer." Direct entry to Keyham College was stopped, and the only avenue left open for all naval officers was through Osborne. All were to have a common training (engineering included) until a specified age was reached, and then a proportion of the young officers were to specialise in engineering and become, as stated, "observational engineers." The Selborne scheme did not state anything as to the methods for selecting the particular youths, and not a word as to whether these would be compelled to do duty in the engine-room. Another peculiar feature was that these "engineering" officers were to be interchangeable with their brethren on the upper deck for ordinary deck duties so that they might not lose their chances of promotion to command rank. All this happened eighteen years ago, but in the meantime slight modifications have been made which need not here be set out.

As soon as professional experts had assimilated the details of the Selborne scheme it was keenly and consistently criticised by engineers.

The admission has come at last that the Selborne scheme of training naval engineers has broken down. The First Lord states: "Osborne College is to be closed, and the large amount of time which was previously devoted to engineering is to be curtailed . . . Midshipmen after one year at sea are *to be permitted to volunteer* (italics are the writer's) for engineering and to be given special engineering instruction. Sub-lieutenants (these will be 20 years of age) *to be permitted to specialise* in engineering, officers selected to be turned over to the engineering branch, and to stay for the remainder of their career in that branch."

The last clause in the preceding sentence is a confession of failure on the part of the Admiralty to make the Selborne scheme a success, and therein rests the victory of those who prophesied its failure. It is a notorious fact that the evergreen Lord Fisher of Kilverstone was the author and fashioner of that historic document. Lord Fisher, in his much-discussed volume "Memories" says "My full idea of Osborne was, alas, emasculated by the schoolmasters of the Nation!" There is a true Fisher touch about this cryptic sentence. Faced with failure, he attempts to place the blame on the schoolmasters. No one knows better than he that outside his own little band of followers the innovation was bound to fail. Engineers are not, and never have been, made in that way. In another place he also confesses that a majority of the Board of Admiralty at that period (1902) were against his views, and yet, he persisted. His latest stunt is to "Sack the lot," meaning, of course, the present Government, for what he considers its wasteful expenditure, but he says nothing about the hundreds of thousands of taxpayers whose money has been dumped into the river Medina in a Mad Hatter's scheme to attempt to make "interchangeable observational engineer officers" out of harmless inoffensive young gentlemen, all of whom wanted to be admirals.

This brings me back to the magnificent stand which ENGINEERING made on this vexed question. It was mainly in its pages that professional opinion found an outlet, and it speaks much for the restraint of those who guide its destinies that the last week's issue contained no signs of the jubilation which is felt by those who "stood for the right," and who have been proved to have been right in the attitude which they assumed on this dangerous and expensive experiment.

At the risk of occupying more space than can in these days be spared, reference should be made to the italicised words in this letter. The Admiralty having bungled over the Selborne scheme appears to be about to drift on to another lee shore of failure. Mr. Walter Long, in his statement, observes that "Midshipmen are to be permitted to volunteer for engineering . . . and that sub-lieutenants are to be permitted to specialise in engineering." No one at the Admiralty is so unsophisticated as to believe that the young men who go to Dartmouth College, are all clamouring to be engineers. As plain matter of fact none is doing this. As stated, and the Admiralty know this in a fuller way than I, the average boy who elects to join Dartmouth does so with the very laudable hope that in the fulness of time he will stand upon the bridge of a battleship as the captain in command. In his boyish mind—and small blame to him—engineers are an inferior breed, and yet an innocent First Lord puts his signature to a state document which says that these youths are to be *permitted* to specialise as engineers and remain as engineers for the remainder of their service lives. The whole thing is a farce, pure unadulterated farce, but the seriousness of the situation arises when the question is asked: "What is to become of the Navy if the new scheme also turns out to be a failure?" It occurs to the writer, who knows a little of Navy ways, that "permits" will never be required, or, if so, the number will be negligible. The view of the present writer is that someone's face has to be saved, and that the present urbane First Lord has been turned on to let some of his gilded forbears down easily. This is, I think, the true interpretation of Mr. Long's statement.

Well-wishers of the Navy would despair were it not for the fact that the authorities have in training on the Indus and Fisgard the real stuff for the naval engineering *personnel* of the future. Let the Admiralty modify the existing curriculum and improve it along practical lines and the lads now in training, and those who will follow them on the vessels named, will prove the salvation of those who have up to the present time laid impious hands upon one of the great professions. State documents do not make engineers, and the quicker this simple truth is learned the better will it be for the Nation.

Yours faithfully,

EDITOR, "NAVAL ENGINEERING REVIEW."

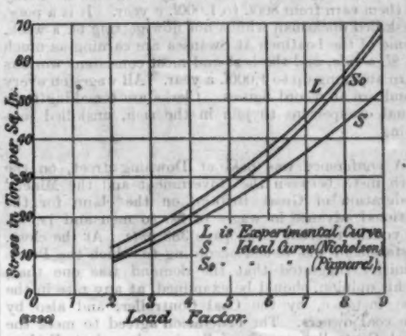
14, Heidelberg-road, Southsea, March 22, 1920.

"THE DEVELOPMENT OF METAL CONSTRUCTION IN AIRCRAFT."

TO THE EDITOR OF ENGINEERING.

SIR,—In the reprint of Major Nicholson's very valuable paper on this subject, in ENGINEERING of March 19, a comparison is made between the experimental characteristics of the various designs and their predetermined characteristics. It is very necessary that the designer shall be able to estimate with reasonable accuracy the failing loads of his spars, and in this connection I should like to draw attention to an error in the method of comparison, the importance of which is perhaps not fully appreciated.

The test specimens were loaded laterally with two concentrated weights symmetrically spaced about the centre and with an axial load in addition. The ratio of the maximum lateral bending moment to the end thrust was always kept constant. Deflections were



measured and the stresses actually calculated from these deflections, a curve of stress against load factor being thus obtained.

In calculating a theoretical stress curve the Perry formula for a uniformly laterally-loaded strut is used, and it will be seen on reference to Major Nicholson's figures that the ideal curve, as he calls it, lies everywhere much below the actual test curve. He advances several reasons for this, one being that the deflection under the two-point loading system is greater than under a uniformly distributed load, and hence the term $P\delta$ is greater in the tests than it should be. The excess is quoted as about 5 per cent. or 10 per cent. The use of Perry's formula for this case is quite unjustifiable, and the greatest portion of the discrepancy between the ideal and test figures is, I think, due to its use.

I have recently had occasion to deduce the exact solution for the stress in a pin-jointed strut carrying two equal concentrated lateral loads, *i.e.*, the condition of the test specimens.

This solution is:—

$$f = \frac{n\,M}{Z}\left(\frac{k}{1-k}\right)\left\{\tan\frac{k\pi}{2}\sqrt{\frac{n\,P}{Q}} - \tan\frac{k\pi}{2}\sqrt{\frac{n\,P}{Q}}\right\}$$

$$\operatorname{cosec}\frac{k\pi}{2}\sqrt{\frac{n\,P}{Q}} + \frac{n\,P}{A} \quad . \quad . \quad (1)$$

where M is the maximum bending moment due to the lateral loads.

k is the ratio of the length between load points to the length of the strut.

P is the end load.

Q is the Euler failing load of the strut.

A is the cross-sectional area of the strut.

Z is the modulus of the section.

n is the load factor.

To show the effect of applying this correct formula, consider the standard curves L and S for steel, in Fig. 25 of Major Nicholson's paper.

L is an experimental curve obtained from many experiments, while S is the ideal curve obtained by an application of Perry's formula.

From this figure and Table I in the paper the following particulars are extracted:—

$\frac{P}{A}$ under unit load = 2·21 tons per square inch.

$\frac{P}{Q}$ under unit load = 0·0522.

$\frac{M}{Z}$ under unit load = 1·9 tons per square inch.

$k = 0·6$.

Applying equation (1) above the following results are obtained:—

n =	1·0	4·0	6·0	9·0
f =	4·29	20·10	34·5	66·51

This gives the true ideal curve which should be compared with the experimental one. The annexed diagram shows this curve, and also those of Fig. 25 in the paper. It will be seen that the discrepancy is now very small; with a load factor of 9 it is only 3 per cent.

The other results in this paper may require similar revision, and I think then it will be found that great credit is due to the experimenters and designers in obtaining test results which are so near to the theoretical figures.

I am, Sir, yours faithfully,

A. J. SUTTON PIPPARD.

Gwydir Chambers, 104, High Holborn, London, W.C. 1, March 19, 1920.

"RECENT ADVANCES IN THE UTILISATION OF WATER POWER."

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of the 12th inst. you published, on page 355, a letter from Professor A. Rateau, on the subject of my paper on "Recent Advances in Utilisation of Water Power," read before the Institution of Mechanical Engineers, in reply to which I would like to make the following observations.

Professor Rateau appears to have taken exception to a footnote in the paper indicating Dr. Camerer's book entitled "Grundriss der Turbinentheorie" as the source of the information regarding the term "specific speed," and he has put upon it the construction of attributing the authorship of this coefficient to Dr. Camerer.

May I point out that in making this reference it was not intended to be construed in this manner but, in any case, I am thankful to Professor Rateau for having drawn attention to the publication of his coefficient "specific power C_s" prior to the introduction of the coefficient N_s, as it is a fact which appears not to be generally acknowledged. In referring to Dr. Camerer I myself have only followed the example of the most prominent authors on this subject, who have directly attributed the conception of the term N_s to Dr. Camerer.

To mention a few instances only, I would refer to the standard work on the theory of water turbines by Professor Escher, of the Technical University in Zurich, as well as to Professor Zowski, of Michigan University, the latter writing in the Transactions of American Society of Civil Engineers, vol. lxvi, page 370, as follows: "It was in Europe that the method of classification on the basis of N_s was introduced first by Dr. Camerer and Mr. Baushus, and where, since 1905, it has been in general use." Professor Thoma, in his work "Die Wasserturbinen," although he attributes to Camerer the introduction of N_s, states that the original idea emanated from Bauer, published 1899, in his book "Turbinentheorie." Few references to this subject are made in French technical literature, but I find that "La Technique de la Houille Blanche," published in 1912 by Messrs. Dunod et Pinat, Paris, introduces the name of M. Solvatore Spera in this connection.

The coefficient C_s is not unknown to hydraulic engineers, but I venture to suggest that the reason for coupling the name of Camerer to the term of "specific speed" by writers on this subject is to be found in the fact that the coefficient N_s has now been universally adopted as a basis for classification of modern turbines. It is to be observed that whereas the coefficient C_s refers to the power a given turbine would develop under the unit head of 1 ft. when running at 1 r.p.m., the coefficient N_s gives the speed of the turbine when operating under the unit head and developing 1 brake horse-power, and contrary to Professor Rateau's opinion, I submit that the latter term has undoubtedly a wider practical application for which reason, it has been adopted as a standard in preference to the coefficient C_s.

The above explanations will no doubt suffice to show that as far as I am concerned, in referring to Dr. Camerer, I have only followed the generally accepted idea as put forward by the leading writers on the subject since 1905, and which I believe has not on any previous occasion been challenged by Professor Rateau. I am, however, glad that publicity, although late, has been given to Professor Rateau's claim for priority in publishing his coefficient C_s, from which N_s obviously has been derived.

I remain, Sir, yours faithfully,

ERIC M. BERGSTROM, A.M.I.Mech.E.

March 23, 1920.

THE LATE MR. ALEXANDER TRAUTWEILER.—The Swiss Ingenieur und Architekten-Verein mourn the loss of its distinguished and universally-popular secretary, Alexander Trautweiler, who died in Zurich on March 11. Born at Lunfenburg, in the Canton of Aarau, in 1854, he was educated at the Technical High Schools of Munchen and Aarhen, and had his first practical work on the Gotthard Railway. After having been engaged on the Pyrsus Railway in Greece for several years, he returned to Switzerland and took part in the construction of the Brunig Railway, becoming later engineer to this line and the Luzern-Bern line at Luzern. Among his projects was one of a Jungfrau railway and one for a hydraulic power plant at Laufenburg, which is now to be carried out. In 1894 he went to Strassburg to take charge of the electrification of the tramways of the city and district. In 1908 he established himself as consulting engineer in Zurich, and was elected secretary of the Swiss Engineer and Architect Association in 1915. As such he was mainly active in standardisation work and always anxious to settle debatable points by agreement without imposing avoidable rules. His death had been preceded by a long illness.

INDUSTRIAL NOTES.

EMPLOYMENT in February, say the Ministry of Labour, was good on the whole. The resumption of work in the ironfoundries, following on the settlement of the prolonged dispute, resulted in a marked improvement in the state of employment at iron and steel and engineering works, though the shortage of castings was still felt and prevented complete recovery in the engineering trades. There was also an improvement in the shipbuilding trades. In the building trades employment was considerably better than in January and was good on the whole, bricklayers and carpenters being in especial demand. In other trades employment was generally good and about the same as in January. It was little affected by disputes. Changes in rates of wages in February resulted in an increase of over 72,000*l.* in the weekly wages of 370,000 workpeople, while changes in hours of labour resulted in an average decrease of 3 hours per week for 178,000 workpeople. The general level of retail prices of food and other items (including rent) of working-class family expenditure on March 1, 1920, calculated on the basis of the pre-war standard of consumption, was about 130 per cent. above the pre-war level, or about the same as a month earlier. Trade unions with a net membership of 1,539,032 reported 1·6 per cent. of their members as unemployed at the end of February, as compared with 2·9 per cent. a month earlier and 2·8 per cent. at the end of February, 1910. This decrease was due mainly to the improvement in employment in the engineering trades as a result of the termination of the dispute in the foundries. In industries in which workpeople are insured against unemployment under the National Insurance Acts, the percentage unemployed on February 27, including demobilised members of H.M. Forces claiming out-of-work donation, was 4·42. The corresponding percentage for January 30 was 6·10. Omitting the engineering and ironfounding trades, the percentage unemployed on February 27 was only 3·35. The total number of ex-service men and women in all industries claiming out-of-work donation on February 27 was 293,144, as compared with 377,116 on January 30. The number of men on the live registers of the Employment Exchanges on March 5 was 351,018, or a decrease of 92,067 on the total on February 6; the number of women was 52,907, or an increase of 1,008 on the total of February 6. The number of vacancies unfilled on March 5 was 32,625 for men and 47,151 for women, corresponding figures on February 6 being 28,900 and 46,967. Employment continued good in February at coal, iron and shale mines; at tin mines it was fair, while at lead and zinc mines conditions varied in different localities. At quarries it remained good generally. In the pig-iron industry employment continued good, and there was a further increase of six in the number of furnaces in blast, though the total was still 21 below that of a year ago. Consequent upon the termination of the strike at the iron foundries towards the end of January, employment at iron and steel works improved to good, and there was also a very substantial improvement in the state of employment in the engineering trade, though there was still a considerable amount of unemployment and short time. In the shipbuilding trade employment improved to good on the whole. In the tin-plate and most other branches of the metal trades it remained good. In the cotton trade employment continued fairly good in the spinning section and good in the weaving section. In the building trade, employment was good on the whole and better than in the preceding month, notably with painters and plasterers; the shortage of bricklayers and carpenters reported in previous months became intensified. In the woodworking and furnishing, brick, cement, pottery and glass, paper and printing, and food preparation trades employment continued good. With dock and riverside labourers employment ranged from good at some ports to slack at others. The number of trade disputes beginning in February was 122. In addition, 47 disputes which began before February were still in progress at the beginning of the month. The total number of workpeople directly or indirectly involved in all these disputes, new or old, was about 110,000, as compared with about 119,000 in the previous month, and about 280,000 in February, 1919. The estimated aggregate duration of all trade disputes during the month was about 450,000 days, as compared with 1,793,000 days in January, 1920, and 2,316,000 days in February, 1919.

The unions affiliated to the National Federation of General Workers, representing a membership of 1,500,000, met last week-end in London, under the chairmanship of Mr. J. R. Clynes, when a resolution was passed expressing the opinion that the question of payment by results with proper safeguards was worthy of the consideration of the trade unions affiliated to the Federation. According to a statement made by Mr. J. O'Grady this meant that the meeting approved the principle of payment by results without, however, definitely committing itself. The safeguards which the Federation has in view are said to be the following: (1) Where, by reason of the introduction of the 47-hours' week, a workman is not able to earn on piece-work his previous remuneration on the same job, the employer will undertake to recommend that suitable adjustments be made on the piece-work price for that job. (2) That piece-work prices shall be such as will enable a workman of average ability to earn at least 33⅓ per cent. over present time rates. Piece-work prices once established shall not be altered unless the methods of manufacture are changed. (3) Where prices are such that on account of the reduction in hours the workman of average ability is unable to earn 33⅓ per cent. over present rates, the necessary adjustments shall be made. We are informed that the engineering unions are taking a ballot on the question, the papers being returnable on April 28.

Wages which make workers "four-figure men" are being earned in the South Wales ports and industrial districts, says *The Liverpool Courier*. Steel workers and coal trimmers are the plutocrats of labour, for numbers of them are receiving pay which puts them over the 1,000*l.* mark. Head steel workers in Port Talbot district are regularly earning 20*l.* to 25*l.* a week, and in other centres leading steelmen easily earn from 15*l.* to 20*l.* a week. Coal trimmers at Cardiff and Swansea stand in a class by themselves. Many of them earn from 800*l.* to 1,000*l.* a year. It is a poor, unskilled dockman who is not now getting 6*l.* a week. Some of the boatmen at Swansea are earning as much as 8*l.* a tide, and the best and most consistent workers earn anything up to 1,000*l.* a year. All wages on every hand are at record figures. Clerks are forsaking their usual occupations to join in the rich, unskilled jobs going.

A conference was held at Downing-street, on the 18th inst., between the Government and the Miners' Federation of Great Britain, on the claim for the national advance in wages of 3*s.* to men and 1*s.* 6*d.* to youths referred to on page 388 *ante*. At the close, a statement was issued according to which the Prime Minister suggested that the demand was one that, in his opinion, should be examined, at any rate in the first instance, by the Coal Controller, and also by the coal owners. The Federation agreed to meet the Coal Controller on the following day, last Friday. Following this meeting with the Coal Controller, Mr. R. Duncan, Mr. Frank Hodges, secretary of the Miners' Federation, said the conference had not resulted in any change of position so far as the miners were concerned. The matter was further considered at a long conference which took place last Tuesday between the Coal Controller and the men's leaders, when the demand for the above-mentioned advance in wages of men and youths was refused by the Government. At the close of the conference, Mr. Hodges said the situation was a very serious one. He admitted that the Coal Controller had made counter proposals, but he declined, on Tuesday, to give any particulars as to these. He added that the executive would report to the delegate conference on Wednesday, as to the negotiations which had taken place; it would then be for the delegates to consider the position and to arrive at a decision. At Wednesday's conference it was stated that the Government's offer was an advance of 1*s.* 6*d.* per day for men and 6*d.* per day for all workers under 16, or 20 per cent. on all wages other than war wage and "Sankey" money, the offer to take effect as from April 1. The delegates decided to press for the full demand of 3*s.* and 1*s.* 6*d.*, this increase to date from March 1. They also decided to instruct the executive to draw up a form of ballot paper for submission to the adjourned delegate conference, which latter took place yesterday. We shall report the further proceedings in our next issue. Early in the week the South Wales miners spoke of insisting upon their original demand for an advance of 2*l.* per week to which we referred in our last issue, but at the time of writing we do not know whether they still maintain that demand.

"A STEAM ALIGNMENT DIAGRAM": ERRATUM.—We regret that a typographical error occurs in the footnote at the bottom of the first column of page 304, in our issue. In the second line of this footnote the reference should be to "pages 483 and 484," instead of to "843 and 844" as printed.

SWISS TRADE EXHIBITION.—The fourth Swiss Trade Exhibition will be held in Basle from April 15 to April 29. The object of the exhibition is to promote the sale of Swiss products on the home market and to encourage export. Information can be obtained from the Swiss Legation (Commercial Department); the Swiss Bank Corporation, London; the London Agency of the Swiss Federal Railways; and from the Swiss Consulates in Manchester, Liverpool, Glasgow and Hull.

OIL-FIRED COOKING RANGES.

ALTHOUGH oil fuel has now been in use for many years for steam raising on our naval ships its employment for cooking is of much more recent introduction. For several years the anomaly of having to take on board considerable quantities of coal or coke for use in the galleys existed on a number of vessels fitted with oil fuel burning apparatus, but in 1913 the Admiralty decided to experiment with oil-fired cooking galleys, and consequently Messrs. Manlove, Alliott and Co., Limited, of 41 and 42, Parliament-street, Westminster, London, S.W. 1, were requested to design and construct such apparatus.

After much experimental work, satisfactory results were obtained, and our illustration, Fig. 1 on the opposite page, shows a large oil-fired cooking range comprising two ovens, a hot closet, two cooking boilers, a hot-water boiler and a hot plate, all of which are heated by means of two oil-fuel furnaces. This range is capable of cooking food for about 300 men. Either crude Texas oil, shale oil, or crude Mexican oil may be used as fuel, the oil being forced into the burners and atomised by air at a pressure of about 40 lb. per sq. in. The electrically-driven air compressor, by means of which the air pressure is maintained, is visible in Fig. 1, and it will be noticed that the compressor is compactly mounted on a cylindrical air receiver. The oil container is filled from the main oil storage tank by means of a hand pump of the lever type. The air compressor, it may be mentioned, is fitted with an unloading device for reducing the supply of air when necessary, as for instance, after the whole range has thoroughly heated up. The air compressor is of the single-acting air-cooled type, but the comparatively large volume of the air receiver is sufficient to eliminate any pulsation at the burners. Following Admiralty practice it will be noticed that each furnace is fitted with two burners, only one of which is used at a time, the other being provided as a stand-by for use in the event of one of the burners becoming choked during cooking operations. The burners each consist of a gunmetal body fitted with a steel nozzle and provided with separate connections for oil and air. The supply of oil and air can be regulated independently by means of screw down needle valves. The oil consumption for ordinary cooking is about 15 lb. per hour in each burner.

Ranges of the type above described have the obvious advantage that the dust and dirt, inseparable from solid fuel, are entirely eliminated. Smokeless combustion is obtained, so that flues do not require frequent cleaning, and the cook's work is still further reduced by the fact that the burners can be started up in about 15 seconds and the ovens and hot plate raised to cooking temperature in about 20 minutes. To start the burner it is only necessary to set the motor working, so as to raise the air pressure in the receiver, turn on the air to the burner, place a piece of lighted tow into the furnace and then turn on the oil. The oil then ignites immediately without any preliminary heating of the burner. Another very important advantage possessed by oil fuel in comparison with coal or coke is that, when the latter fuel is used, a considerable drop in oven temperature occurs each time the fire is replenished. This drop may range from 75 deg. to 100 deg. F., and the proper temperature is not usually restored in less than half an hour. There are, of course, no such unavoidable temperature variations in oil-fired ranges, but, at the same time, if it is desired to raise or lower the temperature, the required regulation is obtained by opening or closing the needle valve on the burner.

A number of large ranges of the type illustrated in Fig. 1 have been supplied for land service in H.M. Naval Barracks, where they serve the double purpose of cooking food for the *personnel* and providing means for training naval cooks in their use. The actual example illustrated was installed at Portsmouth. The largest and most interesting marine installation, however, is that supplied by Messrs. Manlove, Alliott and Co., for H.M.S. Hood, with the design and construction of which vessel we deal on pages 397 and 423 of the present issue. The cooking plant on the Hood includes four small oil-fired ranges fitted in the officers' galley and each capable of cooking food for 50 officers. One of these ranges is illustrated by the photograph reproduced in Fig 2. The crew's galley, which is capable of cooking for 1,400 men, comprises three hot-plate ranges (each measuring 8 ft. wide by 3 ft. 6 in. deep by 2 ft. 10 in. high), one fat-frying range, three hot closets, two wet steam cookers, two 90-gallon boiling coppers, two 120-gallon boiling coppers, and two hot-water tanks. Of these appliances the hot-plate ranges and the fat-frying range are heated directly by oil burners, but the others are all heated by steam supplied through reducing valves from the main boilers. When the cooking installation for the Hood was originally planned, it was arranged to heat the steam cooking apparatus above mentioned by means of steam generated in an oil fired vertical boiler placed in the

OIL-FIRED COOKING RANGES FOR NAVAL PURPOSES.

CONSTRUCTED BY MESSRS. MANLOVE, ALLIOTT AND CO., LIMITED, ENGINEERS, NOTTINGHAM.

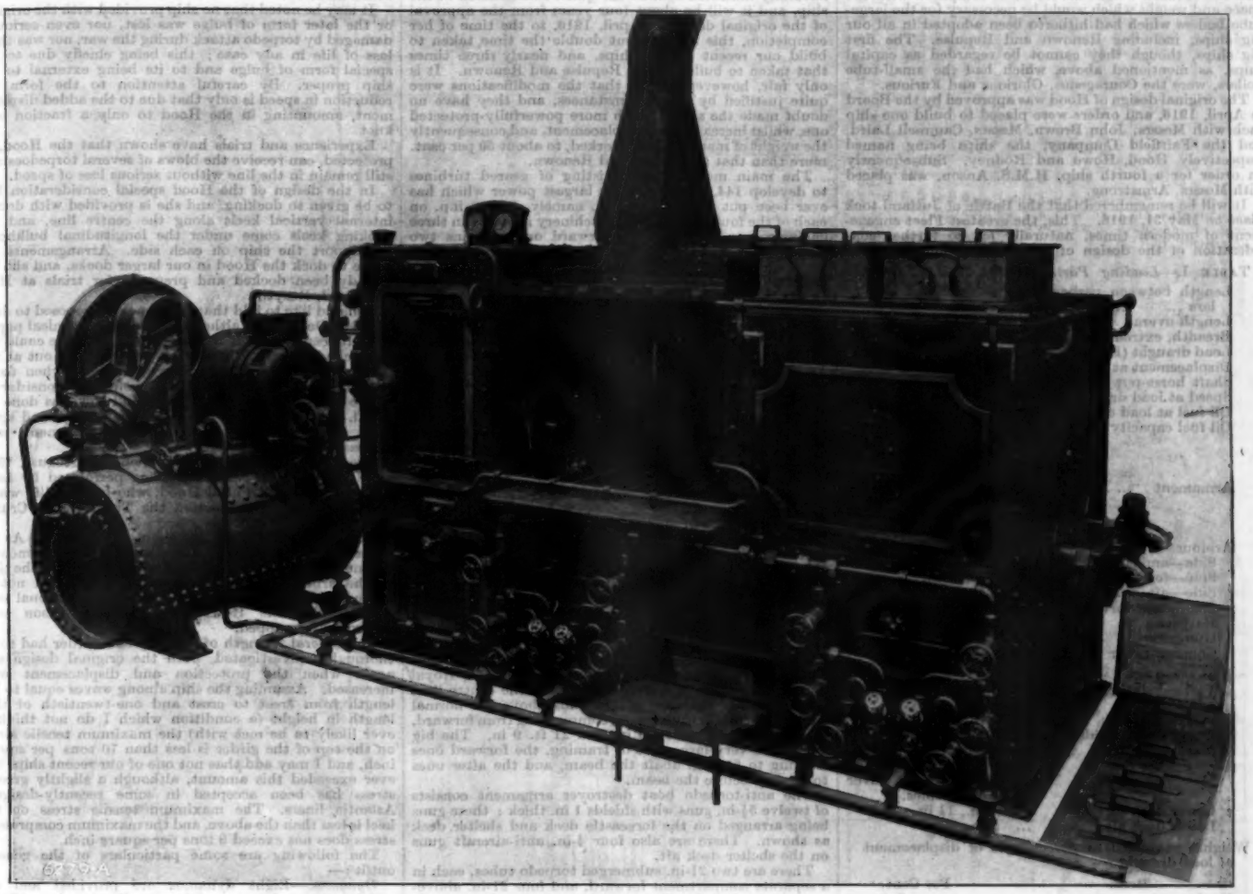


FIG. 1.

galley. This boiler was, in fact, made and tested with very satisfactory results, but, in order to give more space, it was afterwards decided to dispense with the separate boiler and use steam from the main boilers.

The bakery of the Hood is equipped with an oil-fired, double-decked steam tube oven capable of baking 250 lb. of bread in a batch, the time taken to set, bake and withdraw the bread being about 50 minutes. On a trial of the oven in Messrs. Manlove, Alliott's works it was found that a baking temperature ranging from 480 deg. to 500 deg. F. could be reached in 4 hours without giving any attention to the fires; with coal or coke from 12 hours to 15 hours is usually required to raise the temperature sufficiently for baking. The bakery is also provided with an electrically-driven kneading machine, a dough trough and moulding table with proving drawers. The arrangements for supplying oil to the burners on the Hood are, in general, similar to those above described in connection with the land installation, except that a twin cylinder air compressor is used. Similar oil-fired cooking appliances are now being made, for all classes of merchant ships as well as for naval vessels. They are, of course, equally suitable for stationary use on land, in hotels and other institutions, as well as for restaurant cars on railway trains. The system of oil burning can also be employed with advantage in numerous industries in which stills, evaporators and boiling vessels are used, and another promising application is in connection with the heating of buildings by steam or hot water. In all such applications the convenience and economy of oil fuel in comparison with solid fuels are worthy of careful consideration at the present time when fuel and labour are particularly costly.

COST OF PRODUCTION OF HELIUM GAS IN AMERICA.—The American Congressional Committee which recently investigated the question of the industrial production of

FIG. 2.

helium gas now manufactured at plants at Forth Worth and Petrolia, Texas (which were built by the United States Government at a total cost of over 6,000,000 dols.), reports, says *The Board of Trade Journal*, that the present method of extracting gas is impractical owing to the heavy cost of operating the plants. According to this report it costs more to manufacture the gas necessary to inflate a dirigible airship than to build the ship itself, and the committee recommended further investigation into other possible methods of manufacturing helium gas before any further money is spent.

H.M.S. HOOD.*

By Sir EUSTACE D'EYNCOURT, K.C.B., Vice-President.

FOLLOWING on the paper I read before this Institution last year upon "Naval Construction during the War," in which I gave a brief account of all the principal vessels designed and constructed during the war period, I now propose to give an account of H.M.S. Hood, which will complete the series of big ships designed and built for the Navy down to the present time.

Apart from the smaller craft, such as destroyers and patrol boats, of which an immense number were required during the war, the type of large vessel in which we were somewhat deficient in 1915 was the battle-cruiser. It was known that the Germans were building several very important ships of this type, including the Derfflinger, Lützow, Hindenburg, and others to follow. Our own vessels were later to be supplemented by the Renown and Repulse, and there were the very large light cruisers Courageous, Glorious and Furious, but these three latter could not be regarded as battle-cruisers in the proper sense of the term.

I therefore received instructions in 1915 to prepare designs of battle cruisers, embodying the latest ideas in regard to underwater protection, speed, &c. A considerable number of designs were submitted to the Board, but as there were no large berths available, it was not possible to place an order before the spring of 1916, and in March of that year the Board selected a design of the dimensions given below to be worked out in detail and proceeded with. This design formed the original basis for the design of Hood, having the same length and breadth as the Hood, but of considerably less draught, viz., 25 ft. 6 in. normal and 29 ft. deep, with a displacement of 36,300 tons on a length of 810 ft. between perpendiculars. The speed was to be 32 knots, with machinery of 144,000 shaft horse-power. The armour, which was approximately equivalent to that of the Tiger, consisted of an 8-in. belt and 9-in. barbettes. The armament was to be eight 15-in. guns and sixteen

* Paper read before the Institution of Naval Architects, March 24, 1920.

5½-in. guns, together with two 21-in. submerged torpedo tubes.

I strongly advocated the adoption in this design of small-tube boilers, and these were accordingly included for the first time in the design of a capital ship. This feature had the most marked influence on the whole design, on account both of the smaller space occupied and the reduced weight involved, as compared with the space and weight which would be necessary for the large-tube boilers which had hitherto been adopted in all our big ships, including Renown and Repulse. The first big ships, though they cannot be regarded as capital ships, as mentioned above, which had the small-tube boilers, were the Courageous, Glorious and Furious.

The original design of Hood was approved by the Board in April, 1916, and orders were placed to build one ship each with Messrs. John Brown, Messrs. Cammell Laird, and the Fairfield Company, the ships being named respectively Hood, Howe and Rodney. Subsequently an order for a fourth ship, H.M.S. Anson, was placed with Messrs. Armstrong.

It will be remembered that the Battle of Jutland took place on May 31, 1916. This, the greatest Fleet engagement of modern times, naturally led to further consideration of the design of the Hood, which had only

TABLE I.—*Leading Particulars of H.M.S. Hood.*

Length between perpendiculars	810 ft.
Length overall	860 ft.
Breadth, extreme	104 ft.
Load draught (L.W.L.), mean	28 ft. 6 in.
Displacement at load draught	41,200 tons.
Shaft horse-power of engines	144,000.
Speed at load draught	31 knots.
Oil fuel at load draught	1,200 tons.
Oil fuel capacity	4,000 tons.
Armament	8 15-in. B.L. 12 5·5-in. B.L. 4 4-in. H.A. 2 21-in. T.T. submerged. 2 double 21-in. T.T. above water.
Armour—	
Side—amidships	12 in., 7 in., 5 in.
Side—forward	6 in., 5 in.
Side—aft	6 in.
Bulkheads, forward and aft	5 in., 4in.
Barbettes	12 in.
Gun-houses	15 in., 11 in.
Conning-tower	11 in., 9 in.
Protection—	
Vertical plating, magazines, &c.	1½ in.
Forecastle deck, amidships	2 in.
Upper deck, amidships	1 in.
Main deck	1½ in. flat; 2 in. slope. (Increased to 3 in. over magazines.)
Lower deck forward	1 in., 1½ in.
Lower deck aft	1 in., 3 in.

Weights expressed as percentages of displacement at load draught :—

Item.	Per Cent.
Equipment	2·0
Armament	12·5
Machinery	13·0
Oil fuel	3·0
Armour and protection*	33·5
Hull*	36·0
	100·0

just been ordered; and in view of the damage which was done to our own battle cruisers and also to the German ships of similar type, it was deemed advisable to increase the armour protection, if possible. As the result of very extensive investigations, it was found possible, by accepting a deeper draught and a slightly reduced speed, to add very considerably to the protection of the vessels as already designed, without serious modification to the design of the ship as a whole. Accordingly, in September, 1916, definite proposals for increased protection were submitted. The alterations were of a very radical character, the armour belt being increased from 8 in. to 12 in., and the barbettes from 9 in. to 12 in.; and certain increases were also made in the deck protection. The particulars, as thus finally decided, are given in Table I. At the same time the eight 15-in. gun mountings had their design modified to admit of an elevation of 30 deg., and certain other modifications were made both in the torpedo armament and also in the arrangements for preventing the flash penetrating to the magazines—a form of protection which was elaborated for all our ships at this time. All these increases involved an additional weight of nearly 5,000 tons, the legend displacement of the Hood becoming finally 41,200 tons when carrying 1,200 tons of fuel; the ship then having a draught of 28½ ft., and a draught of 31½ ft. with full fuel load, viz., 4,000 tons.

The original length and beam of the ship were maintained as before. Some extra plating had to be provided on the decks for strength purposes, but the under-water protection against torpedoes, which had proved very efficient, was retained, as in the original design. I should mention also that the stability conditions were such that the increased displacement could be accepted whilst still maintaining a very satisfactory metacentric height.

* The plating of the decks and side is required to be of such thickness for strength that it contributes very materially to protection. The weight of this plating is, however, included in "Hull."

All the modifications made in the design after the Battle of Jutland were considered in consultation, not only with the Board of Admiralty, but with the Commander-in-Chief, involving, as they did, special arrangements for the fire and torpedo control, arrangement of bridges, &c.; and it was not till 1917 that the design was finally approved in all its details. This change naturally militated against the quick construction of the ship, and it will be about four years from the approval of the original design in April, 1916, to the time of her completion, this being about double the time taken to build our recent capital ships, and nearly three times that taken to build H.M.S. Repulse and Renown. It is only fair, however, to say that the modifications were quite justified by the circumstances, and they have no doubt made the ship a much more powerfully-protected one, whilst increasing her displacement, and consequently the weight of material to be worked, to about 50 per cent. more than that of Repulse and Renown.

The main machinery, consisting of geared turbines to develop 144,000 h.p., is the largest power which has ever been put through gearing, namely, 36,000 h.p. on each of the four shafts. The machinery is placed in three engine-rooms, of which the forward one contains two independent sets for the outer shafts; the middle and after engine-rooms containing one independent set for each of the inner shafts. This power, which was designed to give 32 knots for the earlier design of 36,300 tons displacement, is expected to give at least 31 knots in deep water at a displacement of 41,200 tons for the Hood as built. The trials, which should take place at an early date, will be of very great interest in this connection. At the extreme deep-load draught of about 31½ ft. a speed of between 30 knots and 30½ knots should, I think, be realised.

The revolutions per minute of the propellers are to be 210 at full speed, and this admits of the adoption of propellers of higher efficiency than many we have had in our capital ships before gearing was introduced, when the revolutions were considerably higher. A good performance may, therefore, be confidently looked for on the speed trials of Hood.

The boilers, 24 in number, as mentioned above, are of the small-tube type with forced draught, and are arranged in four boiler-rooms. It was known that a great number of the German capital ships took advantage of the reduced weight and space occupied by small-tube boilers, and have generally adopted them in their recent designs. It is hardly necessary to say that oil is the only fuel used in Hood.

It will be seen from the plan, page 425, that the main armament of eight 15-in. guns is mounted, as in our recent battleships of the Queen Elizabeth and Royal Sovereign classes, in four turrets, all on the centre line. The heights of the axes of the guns above the normal load water-line for each turret, commencing from forward, are 32 ft., 42 ft., 31 ft. 9 in. and 21 ft. 9 in. The big guns have very large arcs of training, the forward ones training to 60 deg. abaft the beam, and the after ones to 60 deg. before the beam.

The anti-torpedo boat destroyer armament consists of twelve 5½-in. guns with shields 1 in. thick; these guns being arranged on the forecastle deck and shelter deck as shown. There are also four 4-in. anti-aircraft guns on the shelter deck aft.

There are two 21-in. submerged torpedo tubes, each in a separate compartment forward, and four 21-in. above-water torpedo tubes between the upper and forecastle decks; these above-water tubes being a further addition since the original design was made.

The distribution of armour is shown on the drawing, page 425. The 12-in. belt has a length of 562 ft., and a depth of 9 ft. 6 in. Above the main belt is a strake of 7-in. armour to the height of the upper deck, and above that again there is 5-in. armour between the upper and forecastle decks. The side armour all slopes outward from below, as seen on the section, so that the virtual thicknesses are really somewhat greater, as the shell cannot thus hit the armour normally. There is thick plating behind all the armour, varying from 2 in. over the greater portion to 1½ in. and 1 in. elsewhere.

The gun shields for the turrets are of improved shape, with rather flatter roof than formerly, and the armour has a thickness of 15 in. in front, 12 in. and 11 in. on the side, with a thick roof plate. The conning-tower arrangements have been very specially considered, and arrangements made, in addition to the admiral's conning-tower, for torpedo and 15-in. gun control towers, and 5½-in. gun-control, revolving hood with rangefinder, in addition to the rangefinders provided in each turret. There are also smaller rangefinders in connection with the different controls.

The torpedo protection consists of the bulge arrangement, with an outer compartment of air and an inner one specially strengthened with the necessary separating bulkheads, &c. This protection extends throughout the whole length of the machinery spaces and magazines, and it can be said that it renders the ship as safe against attack from torpedoes under water as she is against gun attack above water.

The oil-fuel tanks are arranged along the sides, thus giving additional protection.

It is a somewhat curious coincidence that the first series of recent experiments on under-water protection should have begun by a set of trials of torpedo charges against the old Hood, of the old "Royal Sovereign" Class built in 1893. Developing the lessons learnt from these trials, which took place in the years immediately preceding the war, the bulge protection was first designed and fitted at the commencement of the war in the old cruisers of the Edgar type, to which I alluded in my last year's paper. A series of experiments was then made at the request of the Admiralty by the late Professor (afterwards Colonel) Bertram Hopkinson, F.R.S., in conjunction with myself, at first under the auspices of the Royal Society. These experiments, which were made on different scales gradually working up to the full size, were of the greatest value, and the original protection fitted to the Edgar was modified and the details of construction as modified have been largely adopted in the Hood. I am glad to have this opportunity of paying special tribute to the work of Professor Hopkinson and to his memory.

It may be noted that no ship provided with the original or the later form of bulge was lost, nor even seriously damaged by torpedo attack during the war, nor was there loss of life in any case; this being chiefly due to the special form of bulge and to its being external to the ship proper. By careful attention to the form the reduction in speed is only that due to the added displacement, amounting in the Hood to only a fraction of a knot.

Experience and trials have shown that the Hood, as protected, can receive the blows of several torpedoes and still remain in the line without serious loss of speed.

In the design of the Hood special consideration had to be given to docking, and she is provided with double internal vertical keels along the centre line, and the docking keels come under the longitudinal bulkheads to support the ship on each side. Arrangements are made to dock the Hood in our larger docks, and she has already been docked and prepared for trials at H.M. Dockyard, Rosyth.

I should like to add that it was never proposed to dock Hood at Devonport, although one of the technical papers stated recently that it was discovered that she could not be docked there. Whenever a design is got out at the Admiralty, or presumably anywhere else, when fixing the dimensions, one of the first points to consider is, where the ship is to be docked; and this was done for Hood, both in the case of the original design and again later when the protection and displacement were increased.

The Hood was successfully launched in August, 1918, at Clydebank, the ceremony being performed by Lady Hood, widow of Admiral Hood, who lost his life whilst gallantly leading into action the Third Battle Cruiser Squadron at Jutland.

The launching weight was about 22,000 tons. As the other three ships of the class which were commenced had none of them reached the launching stage at the time of the armistice, it was subsequently decided not to proceed with them, in view of the international conditions, and the Howe, Rodney and Anson were accordingly scrapped.

The general strength of the ship as a girder had to be thoroughly investigated, both the original design and again when the protection and displacement were increased. Assuming the ship among waves equal to her length from crest to crest and one-twentieth of that length in height (a condition which I do not think is ever likely to be met with) the maximum tensile stress on the top of the girder is less than 10 tons per square inch, and I may add thas not one of our recent ships has ever exceeded this amount, although a slightly greater stress has been accepted in some recently-designed Atlantic liners. The maximum tensile stress on the keel is less than the above, and the maximum compressive stress does not exceed 9 tons per square inch.

The following are some particulars of the general outfit :—

Dynamos.—Eight dynamos are provided and are widely separated, two are driven by diesel engines, two by turbo engines and four by reciprocating engines.

Hydraulic Pumping Engines.—Four hydraulic pumping engines are provided for working the turrets; these and the other more important auxiliary engines are kept well away from the ship's side, as are also the necessary feed tanks.

Pumping and Flooding Arrangements.—Special consideration has been given to this item in the design of the ship, electrical bilge pumps have been provided, and also some 100-ton submersible pumps to deal with any water that may enter the ship. For fire and wash-deck purposes a fire main is run all fore and aft under protection with rising mains at intervals. This fire main is charged from the 50-ton electrical pumps, and also from the 75-ton steam-driven fire and bilge pumps in the engine and boiler rooms.

In the boiler rooms 1,000-ton turbo pumps are fitted; in each engine-room the circulating pumps are arranged to draw from the bilges instead of from the sea, if required. Steam ejectors, each of 300 tons capacity, are provided in the auxiliary machinery compartments and submerged torpedo rooms.

Steering Gear.—The steering gear is of the right and left-hand screw type, with connecting rods attached to a crosshead on the rudder head. Two steering engines are placed in the after engine-room with shafting led through the shaft passages and thence aft to the steering gear. Auxiliary steering on the Williams-Janney principle worked by electric motor is placed in the after steering compartment. The main telemotor system is continued aft, so that this gear can be worked from the main steering positions of the ship. The following steering positions are provided :—

Conning-tower;
Lower conning-tower;
After engine-room;
Steering compartment (auxiliary only).

Steering by hand power is not provided, as it has proved to be of little value with these very big high-speed ships.

Capstan Gear.—The anchors, three in number, each weigh 9½ tons, and the chain cable is of 3⅛ in. diameter. Two cable-holders and a middle-line capstan are provided, all connected to the capstan engine. A third cable holder is provided for the sheet cable for letting go only. At the stern a 3-ton anchor is provided, and the after

HIS MAJESTY'S BATTLE CRUISER "HOOD."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, SHIPBUILDERS, CLYDEBANK.

H.M.S. "HOOD."
BATTLE CRUISER.

Fig. 1.

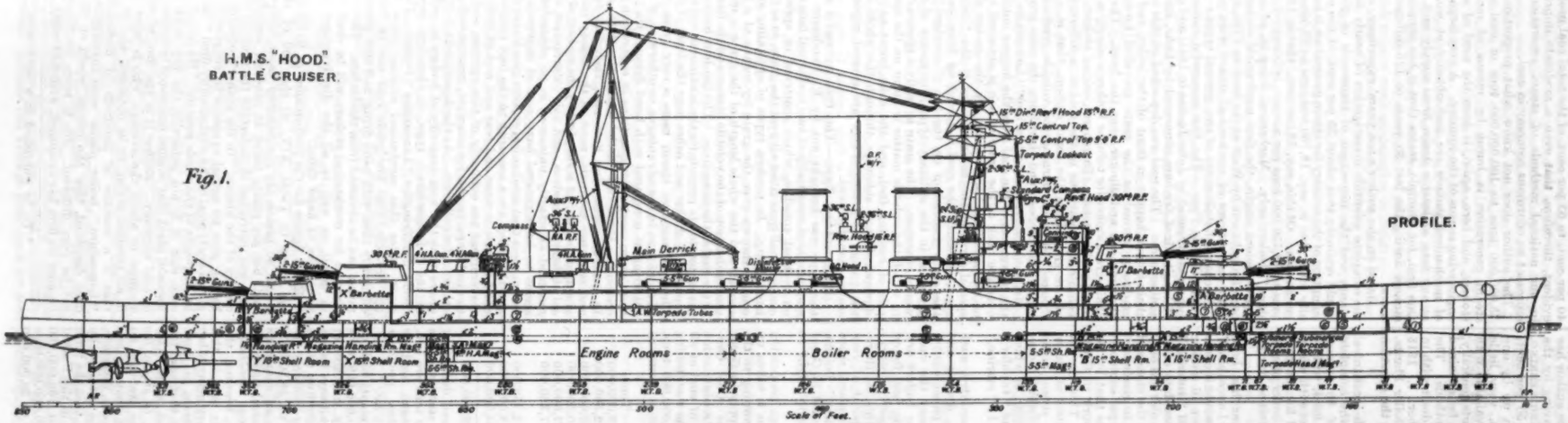
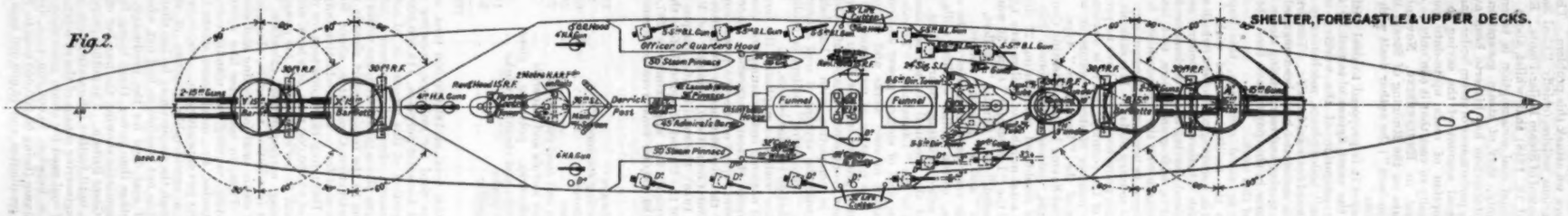


Fig. 2.

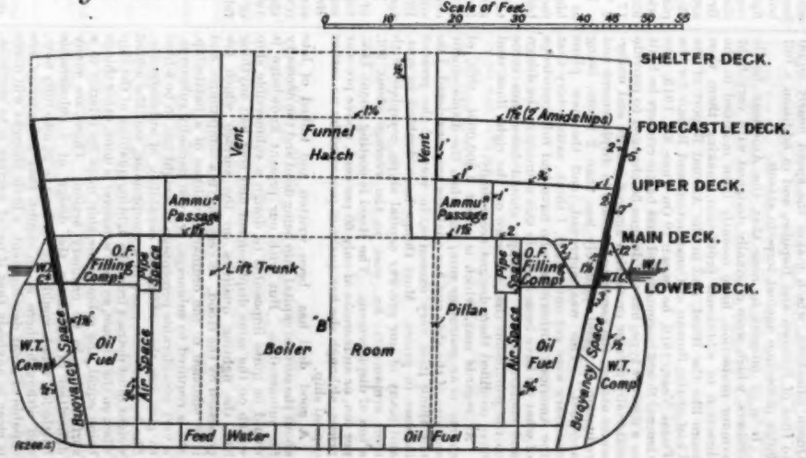


capstan is worked by Williams-Janney gear driven by an electric motor.

Ventilation.—Special attention has been paid in our more recent ships, and perhaps more than any in H.M.S. Hood, to the system of ventilation, which has been worked out on the latest and most scientific principles; a great deal of experimental and research work having been done to get the best results. The main points to be noted are as follows:—

The engine-rooms are ventilated by four 30-in. and three 40-in. supply fans, and four 35-in. and two 50-in. exhaust fans, electrically driven. Each of the auxiliary machinery compartments has two 17½-in. electrically-driven exhaust fans with "natural" supply trunks, all openings being well above the weather decks, in order that ventilation may go on as usual, even in bad weather—a very important point for the comfort and health of the crew. A very complete system of ventilation has been supplied to the seamen's heads, and to all w.c.'s, pantries, sculleries, paint stores, washplaces, &c.; the ventilation being generally by means of exhaust fans leading direct to the open air. The living spaces generally are ventilated by trunks supplied by electrically-driven fans. These trunks have openings so arranged that the air is delivered at a low velocity, and strong draughts which might be objected to are thus avoided and a gradual supply of fresh air, keeping the whole place sweet, is thus ensured. Where necessary, the air is passed through steam heaters for purposes of warming. In all these arrangements care has been taken to maintain as far as possible the transverse watertight subdivision of the ship, by avoiding the piercing of watertight bulkheads. Each of the main transverse compartments is accordingly ventilated independently of any of the other main compartments, and thus the risk of water finding its way from one compartment to another in case of damage is eliminated.

Fig. 3. SECTION THROUGH MIDDLE BOILER ROOM.



Accommodation.—In all our recent designs great attention has been paid generally to the accommodation and comfort of the officers and men. Just before the war a special committee was appointed to inquire into the accommodation of ships, and a report was presented, and all the recommendations of this committee have as far as possible been embodied in our recent ships. The exigencies of the war and the additional requirements which had to be met as the war progressed, to some extent prevented all the recommendations of the committee being carried out; but in the Hood practically the whole of these have been embodied and great improvements have thus been made, recreation rooms being provided, and greater facilities for cooking and similar operations. In fact, a modern ship is in many respects a home of luxury compared to ships even ten or fifteen years old.

Electrically-Driven Boat Hoists.—Boat hoists, fitted with variable speed control gear of the Williams-Janney type, driven by electric motors, are provided, and a weight of 16 tons, that of the heaviest boat, can be lifted and lowered at a rate of 60 ft. per minute.

General Design.—As regards the general design of the ship, the Hood may be cited as an example of what can be achieved by going to a large size. The endeavour has been in her design to embody the armament and armour protection of a first-class battleship, including also good under-water protection against torpedoes, and at the same time to give her the speed of the fastest battle cruisers. It has only been possible to do this by

going to a great length and displacement. The underwater bulge protection is additional to anything provided in our pre-war Dreadnoughts, although these ships had internal bulkheads. The addition of the bulge, which has entirely superseded the provision of torpedo netting, involved a considerably increased weight over and above that of a ship of ordinary form; and although this additional weight was accompanied by a somewhat greater amount of additional buoyancy, it still involved an increased displacement with the accompanying increase in resistance to propulsion.

It may be argued that in such a large ship a great many eggs are placed in one basket, and that a very expensive one, but it would have been quite impossible to combine the speed, armament, and protection in a smaller unit.

In connection with the size of the Hood and general considerations of design, it is, I think, interesting to note that of recent capital vessels built, and taking the chief characteristics of two classes of about the same displacement, in Queen Elizabeth we had a well-armoured ship of about 28,000 tons with eight 15-in. guns, and speed of 25 knots. In Renown and Repulse, of slightly less displacement, viz., 27,000 tons, though of greater length, we had vessels with 7 knots more speed than Queen Elizabeth, but with only six 15-in. guns against eight, and approximately about half the armour protection provided in the Queen Elizabeth. In the Hood we are providing the same armament, viz., eight 15-in. guns, as in the Queen Elizabeth, armour protection fully equal to, and in fact rather heavier in the aggregate than that of the Queen Elizabeth, 6 knots more speed than the Queen Elizabeth, which makes the speed nearly equal to that of Renown and Repulse, and in addition a full bulge protection against torpedo attack.

It is of interest to note that the American battle cruisers, which were originally designed with very light armour protection, have recently been modified in the direction of additional protection, making them thus more like the Hood, and in the Annual Report of the Chief of the Bureau of Construction and Repair for the Fiscal Year, 1919, he says: "On June 24, 1919, the General Board recommended that battle cruisers be built as a distinct type, but the designs be changed to provide materially greater protection against gunfire and underwater attack, the resulting increase in displacement and reduction of speed, probably less than 2 knots, being accepted." This was approved, and the new plans necessary were got out. It is, I think, satisfactory that the American authorities, who have had full knowledge of what we have been doing in this country in the design and construction of warships, should have thus come to the conclusion that we were on the right lines, and have modified their designs accordingly.

As regards cost, which is about 6,000,000*l.*, this, of course, is an enormous sum, but when the displacement and size of the ship and her qualities are considered, I do not think it is very excessive, in view of the present increase in prices. Most things have doubled in cost, and many of our pre-war capital ships, complete with their armaments, &c., cost on the average about 90*l.* a ton of displacement. The Hood is costing about 145*l.* per ton, or an increase of only 60 per cent. above pre-war prices, although she has qualities possessed by no earlier capital ship.

A good deal has been written and talked of late about the surface capital ship being dead and the necessity for submersibles. But with our present knowledge it would be quite impossible to design a submersible ship which on the same displacement and cost had anything like the fighting qualities on the surface which are possessed by the Hood. Every ship is a compromise, and if in addition to the ordinary qualities of a battleship, she is required to submerge, or even partially submerge, a very considerable percentage of weight has to be added to give her this additional capability of submergence. She becomes still more of a compromise, and the added weight must detract from the fighting qualities of the ship when on the surface, so that whatever is done, other things being equal, the submersible ship must be inferior to a surface ship in an ordinary action. There are many difficulties of details in the design of a submersible battleship which would take too long to go into fully now, and although there is no doubt that submarines are capable of great development, a little thought will make it clear to anybody that if naval warfare is to continue, the surface ship of the line must still hold the field as the principal fighting unit of any great navy. This view is apparently shared by other countries who are developing their navies, and both Japan and the United States are building large capital surface ships.

I should like to take this opportunity, on behalf of my staff and myself, of thanking the contractors for the assistance they have given us in getting out working drawings of the Hood; this applies not only to Messrs. John Brown and Co., who have so successfully constructed this, the largest ship ever built for H.M. Navy, but also to the other three firms who, in the earlier stages, helped us with the plans, until the time came when it was decided not to proceed with the three ships ordered from them.

THE PERFORMANCE OF MECHANICAL STOKERS.*

*Exact Data on the Performance of Mechanical Stokers as Applied to "Lancashire" or other Narrow-Fired Boilers.**

By DAVID BROWNLIE, B.Sc.(Lond.), F.C.S., of Manchester, Associate.

ONE of the most serious national questions to-day from an engineering point of view is that of coal economy, and our whole future as an industrial nation will depend largely on how we attack this problem. The author has shown in various articles (chiefly "Coal Saving by the Scientific Control of Steam Boiler-Plants," ENGINEERING, July 12 and 19, 1918) that whilst about 50 per cent. of our national coal consumption is taken up by one operation only, that of steam generation, very little authentic information has hitherto been available with regard to the performance of steam boiler plants generally, and the actual amount of the saving to be obtained by the adoption of more up-to-date methods. The subject is really so vast that it can only be dealt with in sections, and in ENGINEERING, November 1, 1918 ("Exact Data on the Running of Steam Boiler Plants, No. 1 Economisers") the author dealt with the question of economisers.

In this paper it is proposed to deal with mechanical firing, and the exact figures obtained by the complete scientific investigation of the working of 80 typical "Lancashire" boiler plants, mechanically fired, will be brought forward for consideration. The firm with whom the author is associated have been engaged for the past ten years in testing and reorganising steam boiler plants, and the figures in this paper have been obtained during the course of this work.

In order to avoid confusion, this paper has been confined to the results obtained with "Lancashire" boilers, that is, narrow-grate boilers (which would include also "Cornish" boilers, marine boilers, and all similar types of boilers), leaving the consideration of "tubular" boilers, that is, wide-grate boilers, to a later date. An additional reason why the "Lancashire" boiler has only been considered is because it is essentially the standard boiler of the country to-day. It is difficult to give exact figures on this point because we have no proper engineering census of the country, but it is obvious that by far the greater number of steam boilers at work in Great Britain are of the "Lancashire" type. Thus in the article, "Coal Saving by the Scientific Control of Steam Boiler Plants," already mentioned, 250 steam boiler plants were considered representing 27 different industries. The total number of boilers was 1,000, of which 935 were of the "Lancashire" type, 36 were "tubular," 17 "egg-ended," 6 "Cornish" boilers, 1 "marine," 2 "vertical" and 3 "patent" boilers.

In certain very large industries of the country, such as collieries, cotton mills, woollen mills, dyeing and bleaching, calico printing, flour milling, paper manufacture and the chemical industries, almost the only boiler used is the "Lancashire." Tubular boilers are, of course, typical of electric power stations, and found to some extent in steel works and engineering works generally. The question of mechanical firing is, therefore, of much greater interest from the point of view of the present average performance of boiler plants when considered in connection with "Lancashire" boilers, simply because the amount of coal consumed in Great Britain on "Lancashire" boilers is probably eight to ten times that on tubular boilers.

The author wishes to emphasise the large proportion of our total national coal consumption that is taken up for the purpose of steam generation. According to the recent interim report on electric power supply in Great Britain of the Reconstruction Committee (Coal Conservation Sub-Committee), Ministry of Reconstruction (Cd. 9084, 1918), the total annual output of coal of all the mines of the United Kingdom before the war (taking 1913 as typical) was approximately 287,000,000 tons, of which 189,000,000 tons were consumed at home as follows:—

	Tons.
1. Railways	15,000,000
2. Coasting steamers	2,500,000
3. Factories	60,000,000
4. Mines	20,500,000
5. Iron and steel industries ...	31,000,000
6. Other metals and minerals ...	1,250,000
7. Brickworks, potteries, glass works and chemical works ...	5,750,000
8. Gas works	18,000,000
9. Domestic	35,000,000
	189,000,000

Taking this total of 189,000,000 tons, and deducting the amount used for railways, coasting steamers, gas works, and domestic purposes, 118,500,000 tons are left. Some proportion of this amount is, of course, used for blast furnaces, chemical processes, kilns, producer and other gas plants (apart from gas works), &c.

According to the recent report already mentioned, of the Reconstruction Committee, about 80,000,000 tons of coal are used for power production only, inclusive of railways. Deducting 15,000,000 tons for railways leaves the figure of 65,000,000 tons, of which, according to the report, about 90 per cent. is used for power produced by steam raising, corresponding, therefore, to 58,500,000 tons. But in addition to power, there is an enormous amount of steam used for heating and general technical processes. Thus, in industries like dyeing, bleaching, calico printing, tanning, hat manufacture, brewing, the chemical trades, &c., much more steam is used in this way than for power production. Also in very many other industries a considerable quantity of steam is used, even although the amount may be less than that used for power. It is not possible to find out what is the exact amount of coal used for the production of steam for purposes other than power, there being, for example, no statistics available showing the number of steam boilers at work in Great Britain. The author proposes, therefore, to assume, until further information can be obtained by a proper engineering census of the country, that the total amount of coal used for steam generation in the United Kingdom is between 75,000,000 tons and 100,000,000 tons per annum (being 60,000,000 tons to 70,000,000 tons for power production and 15,000,000 tons to 30,000,000 tons for purposes other than power), corresponding to 40 per cent. to 53 per cent. of the total coal used. It is evident, therefore, that even a moderate improvement in our national methods of steam generation would represent an enormous economy in coal.

The author does not know what proportion of the 75,000,000 tons to 100,000,000 tons of coal used for steam generation is burnt by means of mechanical stokers, and here, again, is seen the need of a proper engineering census of the country. A very large number of mechanical stokers are undoubtedly at work, and, at any rate, at least a dozen firms supply such stokers. One firm, for example, states that it has supplied 5,000 stokers during the last 30 years to 125 different steam users.

Based on the author's ten years' experience, including the complete scientific investigation of nearly 500 boiler plants and the inspection of thousands of plants, he would estimate that about 25 per cent. of the coal consumption of the country for steam generation is mechanically fired, that is, say, 18,750,000 tons to 25,000,000 tons per annum. Of this, say, 75 per cent., that is, 14,000,000 tons to 18,750,000 tons per annum, is burnt on "Lancashire" boilers only. Mechanical firing is, of course, of quite ancient origin, the first mechanical stoker having been brought out by Watt as far back as 1785, and after 1840 many types of mechanical stoker were patented.

Mechanical stokers are of two general types:—

(A) *Coking Type.*—The first successful stoker of this type was invented by John Juckes in 1841, and consisted of longitudinal fire-bars connected by links, forming an endless chain. The coal was deposited on this travelling chain from a hopper in front of the boiler, and the fuel gradually burned as the grate travelled forward, discharging ash and clinker over the back. The modern chain-grate stoker for tubular boilers is simply a development of this stoker. In general, coking stokers burn the volatile hydrocarbons of the coal at a different portion of the grate from the fixed carbon, that is, they first "coke" the coal, burning the volatile products driven off by this process, and then burn the coke produced.

In modern types (overfeed) for "Lancashire" boilers the movement of the coal from the hopper until it drops over the back of the grate as ash is obtained by means of reciprocating bars worked by the stoker drive. A special form of the coking stoker is the "underfeed" type, in which the coal is forced up from underneath the grate (instead of on the top ("overfeed") of the grate, as in the ordinary types) by means of a ram or worm conveyor. The grate is really a species of trough in which the volatile matter is burnt on the apex of the pile of burning fuel, and the coke burnt as it travels downwards and sideways through the whole length of the trough or grate. There are several types of such stoker manufactured.

(B) *Sprinkling Type.*—The first successful stoker of this type was brought out by E. Henderson in 1843, and consisted essentially of two horizontal fans revolving on vertical spindles, which scattered or sprinkled the coal in small quantities all over the grate, so as to imitate hand firing. In modern types of sprinkling stoker the coal is thrown over the grate by means of a throwing shovel, and the whole length of the grate is utilised for the combustion of the volatile matter and the fixed carbon of the coal at the same time. The fire-bars have a reciprocating motion to provide for the continuous and automatic removal of clinker and ashes over the back of the grate. There is amongst steam users a very great difference of opinion as to the advantages, or otherwise, of mechanical firing as compared with hand firing. On this question, as on most other questions in connection with coal economy, there are little authentic data available. In general engineering literature, including text-books and reference manuals, most of the scanty information given on the subject is supplied by the makers of mechanical stokers themselves, and this information cannot be regarded as exactly unbiassed in its character. There seems to be a general hazy sort of impression among steam users that mechanical stokers give higher efficiency, and that they are a necessity to the best results, but the chief trouble is wear and tear and cost of upkeep. The Government are evidently of this opinion, and the Coal Control Department, for example, recommends mechanical firing for collieries. As the department is presumably aware that the vast majority of boilers in collieries are of the "Lancashire" type, it therefore recommends mechanical firing for "Lancashire" boilers. The department states that mechanical stoking saves labour in the fire-hole, that low-grade coal can be burnt more efficiently than with hand firing, and that greater evaporation can be obtained from the boilers. The advantages claimed for mechanical stokers will be dealt with later in detail, as well as all the disadvantages urged by advocates of hand firing.

Exact figures for the performance of 80 typical plants are given in Table XIV, at the end of the paper. These 80 plants are not selected cases, either good or bad, but are plants taken at random, according as his firm was instructed to undertake the work by the various owners of the plants. In the author's opinion, although he can give no actual evidence to support it, these 80 plants are typical of the mechanically-fired "Lancashire" boiler plants of the whole country. He found by experience that it is not generally the firm with the most wasteful plant that is most interested in modern methods of coal economy. Rather it is the firm whose plant is average, or above the average, who is more interested in all possible saving to be obtained, and he feels sure that if a number of hundreds of mechanically-fired "Lancashire" boiler plants were investigated on the lines described, that the results would on the average not be very different. He is more convinced of this because his firm has examined, without testing, hundreds

* Paper read before the Institution of Mechanical Engineers on March 19th.

* To be published in a later issue.

of mechanically-fired boiler plants, and found them to be all run on the same general lines as the 80 plants.

Before considering the results, he would like to add that on each of the plants a most complete scientific investigation was carried out, not only for one working day, but also for one week, as a check test. The object of the test was to find out the exact normal every-day working conditions of the plant, particularly as regards efficiency, so that a scheme of reorganisation could be devised for the more economical production of steam. In every case the boiler-house staff worked the plant as usual, and at the end of the tests the water level in the boilers and the general conditions of the fires was the same as at the commencement. Taking the various items which require some explanation in detail :—

The fuel was weighed accurately in the usual manner, depending on the circumstances of the plant. The greatest care was taken to get thoroughly average samples of the fuel, and the heating value was determined in every case with the oxygen bomb calorimeter direct in the fuel as fired.

With regard to the water evaporated, various methods were used, depending on circumstances, but generally the method adopted was the use of a well-known make of pressure-type hot water meter, calibrated before each test, and working between the boiler feed pump and the boilers. The old method of weighing the water direct in tanks, which was sometimes used, is, of course, very cumbersome, and almost impossible for regular weekly recording, such as is necessary on a properly-organised boiler plant. Some form of water meter is, therefore, essential. Whichever type is adopted, the author strongly recommends the additional installation of a calibrated tank of, say, 500 gallons to 1,000 gallons capacity, so that the accuracy of the meter in use can be checked at any time.

The feed water was analysed by the Wanklyn soap-test method before and after boiling, giving the permanent and temporary hardness. The temperature of the feed water before and after the economisers, the draught at various points, the temperature of the flue gases before and after the economisers, the steam pressure, and the temperature of the superheated steam, were taken every half hour and averaged.

As regards the percentage of CO_2 in the flue gases, a CO_2 recorder was fixed on the plant, and the percentage of CO_2 recorded at the rate of about 20 analyses per hour. On the week's trial, the samples of gas were taken from the side flues of each boiler in rotation, allowing as a rule about 12 hours (240 analyses) on each boiler.

With regard to the steam or power used as an auxiliary to the production of steam, in the case of an engine, the indicated horse-power of the engine was taken, and from the type of engine used a very good idea was obtained of the steam used. Thus, for the ordinary enclosed, forced lubrication, high-speed engine in use for driving forced or induced draught fans, an average figure is 35 lb. of steam per indicated horse-power. In the case of a motor drive the power used is, of course, very easily determined. The difficulty is in connection with steam used in the form of steam jets, either under or over the fire-bars. An apparatus was devised for the purpose of estimating the amount of steam issuing from nozzles, consisting of an enclosed cylinder, connected with a long condensing coil. In determining the steam used, the steam pipe and nozzles, or heavy casting with series of small holes, or other apparatus used, is placed bodily in the enclosed cylinder, and coupled up in exactly the same manner as when under the fire-bars. The steam passes through the cylinder and the coils, which are immersed in cooling water, and are open to the air at the end, and the steam used over a period of several hours weighed direct as condensed water. This apparatus is found to be very simple and convenient, and gives absolutely accurate results.

Another final point to be borne in mind, in considering the results, is that the general methods of running steam boiler plants, both hand and mechanically fired, are out of date. A mechanical stoker, like any other mechanical device, has to be used with a certain amount of discretion, and if this is lacking one can hardly blame the mechanical stoker. In considering, therefore, the advantages and disadvantages, the facts with the present general out-of-date methods in vogue have first been stated, and then the facts that would obtain if modern scientific methods of control were adopted.

Detailed analysis of the results of the eighty tests, together with advantages claimed for mechanical firing and the disadvantages urged against it.

A. General Analysis.

1. *Plants Represented.*—The 80 tests represent the boiler plants of 18 woollen mills, 13 paper mills, 12 explosive factories, 11 dye works, 5 cotton mills, 4 chemical works, 4 engineering works, 2 calico printers, 2 dyeing and cleaning works, 2 hat works, 2 hosiery mills, and 1 general textile mill, and are, therefore, a good average selection of the mechanically-fired "Lancashire" boiler plants of the country.

As regards the size of the plants, these are quite representative, varying from the largest plant of 16 boilers, with an annual coal bill of 79,000 tons, down to plants of one boiler, with a smallest annual coal bill of 950 tons. The total annual coal consumption on the whole 80 plants is approximately 715,000 tons, and the total number of boilers 290. The number of different makes of mechanical stoker included in the tests is 8, 3 being sprinkling and 5 coking.

2. *Price of Coal Used.*—The actual price paid for the coal used on the various plants has not been given, because these figures would be of no interest, as the 80 plants were tested during a considerable number of years, and, of course, the price has varied enormously. At the present moment the average price paid for coal throughout the country will probably be about 30s. The increase in the price of coal during recent years has, of course, been sensational. According to the evidence given before the Coal Inquiry Commission by Mr. A. L. Dickinson, Chairman of Finance Board and Financial Adviser to the Coal Controller, the average value per ton at the pit head of the coal raised for the different years is as follows :—

	s.	d.
1908–1913	8	9
1914	9	11½
1915	12	5½
1916	15	7½
1917	16	8½
1918	24	10

3. *Analysis of Feed Water.*—As will be seen from Table XIV, of the paper, there is a great variation in the quality of the boiler feed water, varying from 3 deg. total hardness to 28 deg. and averaging, say, about 9 deg. total hardness. This is, however, about normal —that is to say, these 80 plants were neither better nor worse than average plants. In the 250 tests the average figures were about 12 deg. total hardness. It is obvious, of course, that scale in the boilers will reduce very seriously the efficiency, whether for mechanical or hand firing.

4. *Temperature of Feed Water Before and After Economisers.*—In this respect the 80 plants are distinctly better than the average. In ENGINEERING, November 1, 1918 ("Exact Data on the Running of Steam Boiler Plants, No. 1 Economisers"), the author gave the figures for 250 plants, and the figures can be compared as follows with the 80 plants in Table I :—

Table I.

Division according to Saving Obtained.	80 Plants Mechanically Fired.		250 Plants (24 per Cent. Mechanically Fired and 76 per Cent. Hand-Fired).	
	No. of Plants.	Per Cent.	No. of Plants.	Per Cent.
No economisers installed ..	9	11·25	95	38·00
Less than 5 per cent.	2	2·50	14	5·60
5 per cent. to 7½ per cent...	2	2·50	15	6·00
7½ per cent. to 10 per cent. ..	13	16·25	23	9·20
10 per cent. to 12½ per cent...	14	17·50	33	13·20
12½ per cent. to 15 per cent. ..	20	25·00	46	18·40
Over 15 per cent.	20	25·00	24	9·60
	80	100·00	250	100·00

The mechanical stokers have, therefore, better conditions, from the point of view of obtaining efficiency, than the average as regards assistance from economisers.

5. *Method of Draught.*—As has already been seen, out of the 80 plants, 65 plants are working on chimney draught, whilst 12 plants are working with induced draught and three plants with forced draught. Mechanical stokers (except underfeed coking) will work just as well with induced draught as with ordinary chimney draught, whilst the underfeed coking type will only work with mechanical forced draught.

6. *Boiler Pressure.*—The figures for the boiler pressure can be summarised as in Table II :—

Table II.

—	80 Plants Mechanically Fired.		250 Plants (24 per Cent. Mechanically Fired and 76 per Cent. Hand-Fired).	
	No.	Expressed as Percentage.	No.	Expressed as Percentage.
1. Over 160 lb. pressure	4	5·00	7	2·80
2. 120 lb. to 160 lb. pressure ..	20	25·00	37	14·80
3. 100 lb. to 120 lb. pressure ..	20	25·00	35	14·00
4. 80 lb. to 100 lb. pressure ..	14	17·50	55	22·00
5. 60 lb. to 80 lb. pressure ..	15	18·75	71	28·40
6. Below 60 lb. pressure	7	8·75	45	18·00
	80	100·00	250	100·00

The question of working pressure is not of much importance in connection with the economical generation of steam, but regarding the question of economy by the economical utilisation of steam, a serious national loss is undoubtedly caused by the steam pressure of boiler plants being generally much too low. Here, again, the 80 mechanically-fired plants have a slight advantage in working conditions, as they have been applied to rather more modern plants, as indicated by the higher average steam pressure.

7. *Superheaters.*—Out of the 80 plants, 17 are fully equipped with superheaters, 18 are partially equipped, and 45 (56·25 per cent.) have no superheaters at all. Similarly, as described with economisers (paragraph 4), these mechanical stoker plants are obtaining more than average assistance for efficiency from superheaters. Thus, in the 250 tests, 170 plants (68 per cent.) were not fitted with superheaters.

B. Analysis of Advantages and Disadvantages.

1. *Efficiency.*—It is claimed that mechanical firing is more efficient than hand firing, and most extraordinary statements on this point are made by some firms supplying mechanical stokers. One firm states that the average saving is 10–40 per cent. of the coal bill, and instances are given of even 52·5 per cent. saving. Another firm states that on an average the saving obtained in two years will pay for the cost of installation. Most mechanical stoker firms claim that mechanical stoking is bound to be more efficient than hand firing, because it is not necessary to open the doors to clean out. The details of tests generally given in makers' catalogues are equally extraordinary. Many of the results of these tests are very difficult to follow, and it is often not clear whether they apply to the boiler only or to economisers and superheaters as well. However, some specimen results are 78·43 per cent. efficiency on "Lancashire" boilers and economisers, and 70·02 per cent., 72·58 per cent., 76·62 per cent., and 81·1 per cent. on "Lancashire" boilers only, and so on. These statements give the impression that such results are a matter of course if mechanical firing is adopted.

The average net working efficiency for the 80 plants, including economisers and superheaters, after deducting the steam or power used to produce steam, is approximately 59·0 per cent. For the boilers only the figure is approximately 53·0 per cent. The corresponding figure for the 250 plants (76 per cent. hand firing and 24 per cent. mechanical firing), is 60·09 per cent., and the figures can be summarised as in Table III :—

Table III.

—	80 Plants, Mechanically Fired.		250 Plants (76 per Cent. Hand-Firing and 24 per Cent. Mechanical Firing).	
	No. of Plants.	Per Cent.	No. of Plants.	Per Cent.
Over 80 per cent. ..	1	1·25	2	0·8
75 per cent. to 80 per cent.	2	2·50	9	3·6
70 per cent. to 75 per cent.	2	2·50	13	5·2
65 per cent. to 70 per cent.	17	21·25	30	12·0
60 per cent. to 65 per cent.	11	13·75	44	17·6
55 per cent. to 60 per cent.	16	20·00	62	24·8
50 per cent. to 55 per cent.	15	18·75	47	18·8
Less than 50 per cent.	16	20·00	43	17·2
	80	100·00	250	100·0

As already stated, it must be remembered that the 80 plants are obtaining assistance above the average from economisers and superheaters, and if the hand-fired plants were equipped to the same extent, the figure of 60·09 per cent. efficiency would be about 61·5 per cent. The approximate figures which the author has for about 350 hand-fired "Lancashire" boiler plants show an average net working efficiency of about 62 per cent. These results show, therefore, that mechanically-fired plants as at present worked are actually obtaining worse results than hand firing.

In the 250 tests, 190 plants with hand firing were giving 57·8 per cent. efficiency, as compared with 60 plants mechanically fired with 61·4 per cent. efficiency, but the latter included some chain-grate stokers on tubular boilers. It will probably not be very far wrong to assume that there is little or no difference between mechanical and hand firing with the present methods of running boiler plants, and in both cases the average net working efficiency, including economisers and superheaters and deducting the steam or power used auxiliary to the production of steam, is only about 60 per cent. The general idea that mechanical stoking on "Lancashire" boilers throughout the country is giving higher efficiency, as compared with hand-firing, is a complete fallacy, and after reading the extraordinary results given in makers' catalogues, it is somewhat of a shock to arrive at an average net working efficiency of, say, 59 per cent. As seen from Table XIV, in actual practice mechanical stoking is giving all kinds of results, from 40–80 per cent. efficiency, and typical hand-fired plants will show about the same variation.

The question of the quality of the coal used is of the greatest importance in considering the performance of mechanical stokers. Many of the results given in mechanical stoker makers' catalogues are admittedly obtained with very very high quality coal, and with coal of this nature it is almost as easy to get good results with hand firing. If boiler plants were run on correct scientific lines, it is very difficult to say what the comparative results would be. If the coal is of good quality mechanical firing would probably give a slight advantage ; with medium quality coal there would be no difference, and with poor quality coal hand firing would have a slight advantage. Under modern conditions hand firing would be, of course, considerably improved, and average results of 75 per cent. efficiency would be obtained, so that the advantages of mechanical firing in this respect can be regarded as nil.

2. *Percentage of CO_2.*—Following from paragraph 1, it is claimed that mechanical stokers give a higher per-

centage of CO_2 in the flue gases, and that less air is required per pound of fuel for combustion. For the 80 plants the approximate average figure for CO_2 is 8·25 per cent., and the figures can be summarised as follows :—

TABLE IV.

—	80 Plants Mechanically Fired.		250 Plants, Typical of the Whole Country (76 per Cent. Hand-Fired and 24 per Cent. Mechanically Fired)	
	No. of Plants.	Nearest per Cent.	No. of Plants.	Nearest per Cent.
1. Very good over 12 per cent. ..	3	4·0	4	1·6
2. Good, 10 per cent. to 12 per cent.	12	15·0	17	6·8
3. Medium, 8 per cent. to 10 per cent.	24	30·0	64	25·6
4. Poor, 5 per cent. to 8 per cent. ..	35	45·0	144	57·6
5. Very bad under 5 per cent. ..	5	6·0	21	8·4
Total	79*	100·0	250	100·0

* One plant CO_2 not determined.

The average figure for the 250 plants as above was about 7·1 per cent., and for 350 cases of hand firing only about 7·5 per cent. According to these figures, therefore, mechanical firing is giving very slightly better results than hand firing, but in both cases the general results throughout the country are poor, and could be greatly improved. If modern scientific methods were adopted, the author thinks that mechanical firing would give slightly better results, but the difference is not great. It is certainly not at all correct to claim any great advantage for mechanical firing in this respect. It is obviously an advantage in mechanical firing that the fire-doors need never be opened to fire the coal and to clean out. This advantage is, however, largely counterbalanced by the fact that on boiler plants, as generally worked to-day, mechanical fires tend to get thin at the back, and excess air is admitted at this point. The net result is a slight advantage only for mechanical firing, as shown by the CO_2.

3. *Life of the Boiler.*—There is a very considerable difference of opinion on this point. It is claimed that mechanical firing ensures longer life for the boiler, because the fire-doors need not be opened, and no cold air rushes in to cause contraction and expansion. This is certainly a very minor claim. From an academic point of view it is no doubt correct, but it is not of very much importance when it is remembered that the average life of hand-fired "Lancashire" boilers is about, say, 20 to 25 years, and any number of such boilers now at work are 30 or even 40 years old. Advocates of hand firing claim that the wear and tear on the boiler is one of the disadvantages of mechanical firing, because of the intense heat produced on one section of the grate only, and because of the deleterious action of the steam jets used. Many instances are given of serious damage to boilers, chiefly in burning the furnace "crowns" of the boiler. It would certainly be far more just to say that mechanical firing as generally worked to-day tends to shorten the life of the boiler. If boiler plants were run on correct scientific lines, the author is of the opinion that there would be no appreciable difference whatever in this respect between mechanical and hand-firing.

4. *Amount of Steam Produced.*—There is also a considerable difference of opinion on this point. Stoker firms generally maintain that more steam per boiler is produced as compared with hand firing. The statements made by some firms are remarkable. For example, it is stated that with one make of stoker 25–50 per cent. more steam is obtained, and with another the amount can be doubled. Many advocates of hand firing are of the opinion that mechanical firing is inferior in this respect. The average figure for the 80 boiler plants is approximately 600 gallons per boiler per hour, calculated for 30 ft. by 8 ft. 6 in. standard boilers. The figure for the 250 plants typical of all industries (76 per cent. hand firing and 24 per cent. mechanical firing) is also about 600 gallons, whilst the figure for about 350 hand-fired plants is still about the same, namely, 600 gallons.

As boiler plants are generally worked to-day it would appear, therefore, that there is no advantage in this respect in mechanical firing, and the extravagant claims, such as 25–50 per cent. more steam, are quite unfounded. It would be interesting to know on what data the Coal Control Board makes the statement that mechanical firing gives increased evaporation. If boiler plants generally were run on scientfic lines, in the author's opinion there would be little difference between mechanical and hand firng and there is no advantage in mechanical firing in this respect

5. *Flexibility of Steam Output.*—Opinion on this point is very divided It is stated as one of the advantages of mechanical firing that the boilers will respond to fluctuating demands for steam better than hand firing. On the other hand it is maintained by many steam users that mechanical stokers cannot respond as well as hand firing, and that they are, therefore, in this respect better adapted for steady loads only, such as cotton mills flour mills, &c. It is not easy to decide this point unless most careful observations are taken, and the exact evaporation noted every half hour. The authors firm have done this many times, and their experience has almost invariably been that with boiler plants as generally run to-day this is a defect of mechanical firing. Ordinary medium quality hand firing will respond to violent fluctuations in demand for steam in a way that is not possible with mechanical firing, whilst with good hand firing there is hardly any comparison. If boiler plants were run on correct scientific lines the advantage would still be with hand firing.

6. *Flexibility in Quality of Fuel Used.*—Here, again, there is a very great difference of opinion. Mechanical stoker firms claim that stokers will burn all qualities of coal, even inferior and refuse coals, to better advantage than by hand firing. Against this it is urged that mechanical firing will not burn inferior coals anything like as well as hand firing, whilst at the same time the wear and tear on the stokers is greatly increased. Further, stokers will only generally give good results with certain qualities of coal for which they are suitable, and the result of installing stokers is to restrict the coal market available. If, for example, a given make of sprinkling stoker is installed, it is not possible to burn any rough coal (in large lumps) or any coal that is very wet. If coking stokers are installed, one can only run "coking" coal, and, again, any rough coal is barred. With hand firing on a plant properly equipped as regards draught any quality of coal can be burnt, according as the value is offered.

With regard to the claim that mechanical firing will burn low-grade coal more efficiently than hand firing, the 80 plants, as seen from Table XIV, include a great variety of coal from high-class washed nuts of 13,033 B.Th.U. and 6 per cent. ash, to very inferior coal of 8,500 B.Th.U. and 19 per cent. ash. The author's experience is that the idea that mechanical firing will burn inferior coals on "Lancashire" boilers more efficiently than hand firing is entirely unfounded, and is in fact the exact reverse of the true circumstances of the case. The advantage in this respect with boiler plants as worked to-day is with hand firing. It must first of all be remembered that no mechanical stoker will handle at all many low grades of fuel. For example, "washer settlings" from coal-washing machines, containing 25–30 per cent. of water, can only be burnt on "Lancashire" boilers by hand firing, and fine coke refuse cannot be burnt on coking stokers.

Taking the inferior coals that can be handled by mechanical stokers, it will be found that the efficiency of mechanically-fired plants is no better, and often worse, than hand firing. The Coal Control Board has gone to the length of recommending mechanical stoking for collieries, where the conditions as regards inferior fuel are the worst of all industries, and, again, it would be interesting to know on what data it has based this opinion. If modern scientific methods were adopted, the same conditions would apply, and generally the difficulties of mechanical stoking increase as the quality of the coal decreases.

7. *Amount of Fuel Burned.*—Stoker firms usually claim that not only is mechanical firing more efficient than hand firing, and therefore more steam produced per pound of coal, but also more coal is burnt per boiler, and therefore the total steam output greatly increased. On the 80 tests the average coal consumption per boiler is roughly 938 lb. of coal per hour, and 24·3 lb. of coal per square foot of grate area per hour. The figures for the 250 plants (76 per cent. hand firing and 24 per cent. mechanical firing) are 798·8 lb. of coal per boiler per hour, and 20·9 lb. per square foot of grate area per hour. The average for about 350 plants, hand-fired "Lancashire" boilers, is found to be approximately 700 lb. of coal per boiler per hour and 19·5 lb. per square foot of grate area.

There seems to be no doubt therefore, that very generally mechanical stokers are burning more coal per boiler per hour than hand firing, on boiler plants, as generally worked in the country at present. If both mechanically fired and hand-fired plants were worked on correct scientific lines, it is somewhat difficult to say whether mechanical firing would have an advantage in this respect. On good quality coal he should say there is very little difference, and 1,000 lb. average quality coal per 30 ft. by 8 ft. 6 in. boiler per hour could be burnt by either method of firing. As the coal becomes inferior in quality, the advantage as regards amount of coal burnt increases with mechanical firing, until a point is reached when mechanical firing will not handle the coal at all, and hand firing must be resorted to.

8. *Black Smoke.*—Most stoker firms claim that black smoke is either completely abolished or greatly reduced. The figures for the 80 plants can be approximately summarised as follows, with the figures for 250 plants as a comparison :—

TABLE V.

—	80 Plants Mechanically Fired.		250 Plants (76 per Cent. Hand-Fired and 24 per Cent. Mechanically Fired).	
	No. of Plants.	Per Cent.	No. of Plants.	Per Cent.
Good	23	28·75	65	26·0
Fairly good	31	38·75	62	24·8
Medium	24	30·00	75	30·0
Bad	2	2·50	43	17·2
Chronic	0	0·00	5	2·0
Total	80	100·00	250	100·0

The results show, therefore, that mechanical firing is giving better results from the point of view of black smoke than hand firing, as boiler plants generally are being worked to-day. This appears to be due to the fact that the fires are, as a rule, somewhat thinner. If boiler plant were operated on scientific lines, there would be probably very little difference between mechanical and hand firing. Many hand plants are working to-day almost completely smokeless, and if better wages and more attention were paid to firemen, and adequate draught provided, black smoke would disappear on both mechanically and hand-fired plants.

(To be continued.)

GERMAN SUBMARINES.*

By A. W. JOHNS, R.C.N.C., Member of Council.

INFORMATION which has been published since the date of the Armistice shows that the danger to the Allied cause from the unrestricted use of German submarines was far more serious than was realised by the general public at the time. It is noteworthy that this menace was caused by a weapon new to naval warfare, and which, until just after the outbreak of war, had not been considered to be of very serious import by the responsible naval authorities. Further than this, it came from a Power which apparently had thought little of the submarine as an efficient weapon of war and had started building them some time after other nations. Possibly this last fact is one for which the Allies have to be thankful. The object of this paper is to give some information as to the types, number, cost and other particulars of the German submarines. A great amount of this information has already been published in Germany by various naval authorities.

—	U86.	U161.
Date of completion	1916	1918
Length, in feet	230	235
Breadth, in feet	20½	21⅞
Draught, in feet	13½	12½
Surface displacement, tons	800	820
Capacity of ballast tanks, tons	140	190
Brake horse-power of engines	2,400 (2)	2,400 (2)
Surface speed, knots	16½	15½
Normal oil fuel, tons	75	46
Total oil fuel	75	107
Brake horse-power of motors	1,180	1,160
Submerged speed	8	8
Torpedo tubes—		
Bow	2	4
Stern	2	2
Guns	1 4·1-in. 1 3·5-in.	2 4·1-in.

—	U135.	U139.	U142.
Length, in feet	275½	302½	320
Breadth, in feet	25	29½	31½
Draught, in feet	14½	15⅞	17⅞
Surface displacement, tons ..	1,240	1,840	2,160
Capacity ballast tanks, tons	370	550	600
Brake horse-power, main engines	3,500 (2)	3,500 (2)	6,000 (2)
Brake horse-power auxiliary engines	900 (2)	450 (1)	550 (1)
Surface speed, knots ..	16	15·8*	18½ (designed)
Normal oil fuel, tons ..	66	102	—
Total oil fuel, tons	220	390	450
Brake horse-power motors ..	1,940	1,760	2,600
Submerged speed knots ..	7	7·4*	8 (designed)
Torpedo tubes—			
Bow	4	4	4
Stern	2	2	2
Guns	1 5·9-in. 1 3·5-in.	2 5·9-in.	2 5·9-in.
Crew	46	—	83

* These speeds are taken from a report found in the bilges of U140, by a representative of the Electric Boat Company, and handed to Constructor-Commander E. S. Land, U.S.N.

—	UB1–17.	UB18–47.	UB48–136.
Length in feet	92	118½	181½
Breadth, in feet	10½	14½	19½
Draught, in feet	10	12½	12
Surface displacement, tons ..	128	265	521
Capacity of ballast tanks, tons	15	29	136
Brake horse-power of engines	60 (1)	282 (2)	1,100 (2
Surface speed, knots ..	6·5	9·0	13·5
Normal oil fuel, tons ..	3·5	22	34
Total oil fuel, tons	3·5	28	69
Endurance	1,600 at 5	6,500 at 5	8,500 at 6
Brake horse-power of motors	120 (1)	280 (2)	760 (2)
Submerged speed, knots ..	5·5	5·8	7·5
Torpedo tubes—			
Bow	2 17·7-in.	2 19·7-in.	4 19·7-in.
Stern	—	—	1 19·7-in.
Guns	1 mach.	1 machine 1 2-in. and later 1 3·5-in.	1 machine 1 3·5-in. and later 1 4·1-in.
Complement	14	23	34

Types.—At least seven distinct type of submarines were laid down by the Germans during the war. There are, however, various classes in each type, the qualities of the classes being modified as the experiences of the war showed to be necessary. This evolution resulted in increase of offensive power—both gun and torpedo—in seaworthiness, in endurance, and necessarily in size. The seven types are as follows :—

(*a*) *The ordinary U-boat* (Fig. 1, page 429), about 230 ft. long, 750–820 tons surface displacement, used

* Paper read before the Institution of Naval Architects, March 24, 1920.

GERMAN SUBMARINES.

Fig. 1. U.161. (ORDINARY U BOAT)

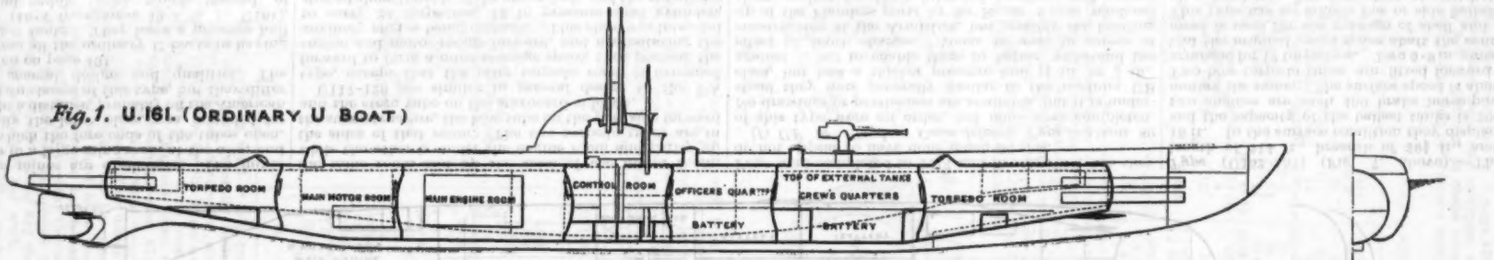


Fig. 2. U.135. (U.A. OR CRUISER TYPE)

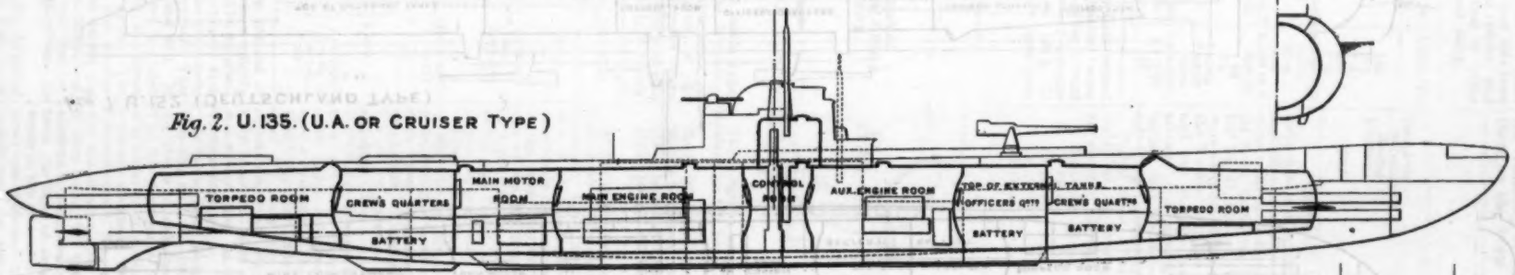
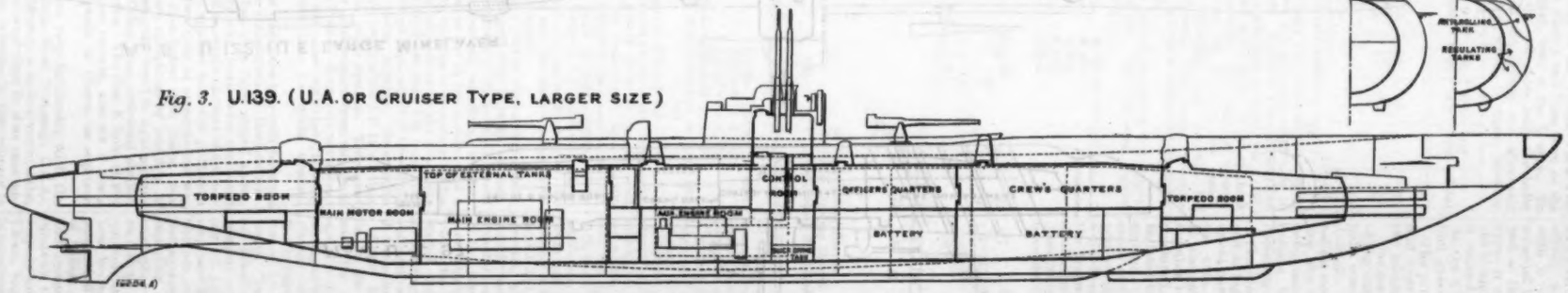


Fig. 3. U.139. (U.A. OR CRUISER TYPE, LARGER SIZE)



for general service work, and intended primarily for attack of warships. These were fitted with two or four bow torpedo tubes and one or two stern tubes. The guns carried were one 4·1 in. in the early class, one 4·1 in. and one 3·5 in. in the middle class, and two 4·1 in. in the latest classes. Particulars of two classes are given on page 428, U161 being one of the last completed.

(b) *The UA or Cruiser Type.*—There are three classes of this type (Figs. 2 and 3, above). They are large boats, especially the two later classes, with powerful gun armament and very large endurance. The three classes are the U135, U139 and U142. The particulars of these are given on the previous page.

The endurance is large, that of U142 being stated as 20,000 miles at 6 knots. U135 has an endurance of 5,000 miles at 16 knots, 8,000 at 12 knots, and 12,000 at 6 knots. The total fuel capacity is taken in arriving at these figures. All three classes are fitted with a range-finder for use with the guns.

Of this type from 35 to 40 were under construction at the time of the Armistice. U139 appears to have been the only boat in commission which had made a voyage. Her commander was Arnold de la Perriere. U141 was complete on surrender, but had seen no service. U135 and U139 are stated to have been completed by the builders in 1917, but apparently much time was taken up in trials and making modifications which were found necessary. U135 had never been submerged, as certain defects which would have been apparent on submergence were not remedied.

It has been stated that the German Submarine Service were not favourably disposed towards these large boats, and that it was considered that if ordinary U-boats had been built instead, the increased number of boats thus available would have won the war.

Although referred to as UA-boats, they and the UB type, referred to later, were lettered as ordinary U's and numbered in sequence with them.

(c) *UB or Coastal Type* (Fig. 4, page 430).—There are three classes of this type, and the particulars given in the table show the stages in evolution of the type.

The displacements increased in nearly arithmetical progression, and the latest class is, except for speed, a superior boat to the earlier U classes. The capacity of the ballast tanks, an approximate measure of the reserve buoyancy in the surface condition, increased from 12 per cent. in the earliest to 26 per cent. in the latest class. The surface speed of the first two classes was poor and not sufficient to overtake merchant ships. They had to wait submerged for their prey. The last class could overtake ordinary merchant ships and sink them by torpedo or gunfire. This was a popular type, as the boats on order reached UB249, the largest number in any type. It was one of the latter class which, late in the war and manned wholly by officers, set out to torpedo the Flagship of the Grand Fleet. The submarine passed the outer defences of Scapa, but was blown up in the second line of defence. The Grand Fleet was not at Scapa at the time. The first two classes were erected in the shipyard, riveted so far as practicable, taken down, and transported by rail to Hoboken and Pola for re-erection. The endurance and seaworthiness of the last class made them capable of proceeding to the Mediterranean by sea. The gradual increase in gun and torpedo armament is noticeable.

(d) *UC or Small Minelayer Type* (Fig. 5, page 430).—These boats are fitted with six open middle-line tubes, sloping slightly aft, and carrying two or three mines per tube. The mines are, therefore, always in water. Releasing gear to each mine is fitted and worked from inside the boat. There are three classes of this type, the two later classes not being greatly different, although both are appreciably larger than the earliest class. The particulars are given in the table on page 431. The first class is a pure minelayer, no torpedo tubes being fitted. The space taken up by the mine tubes prevented internal bow tubes being fitted, but in the middle class two torpedo tubes were fitted in the superstructure forward, and in the last class in the superstructure amidships alongside the conning tower. The middle and last classes had an internal stern torpedo tube. The first class had a single screw. The seaworthiness and endurance were small, and they could only be used for mine-laying in the Channel and on the South-East Coast. The later classes could proceed much farther afield for their operations.

(e) *UE or Large Minelaying Type* (Fig. 6, page 430). These boats are fitted with two horizontal tubes aft,

GERMAN SUBMARINES.

Fig. 4. U. B. 103–117.

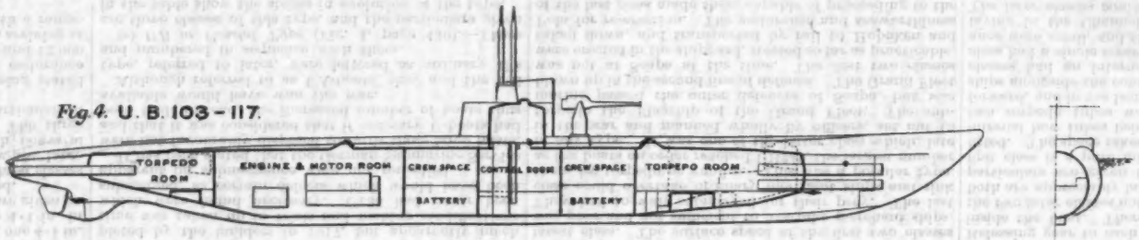


Fig. 5. U. C. 97.

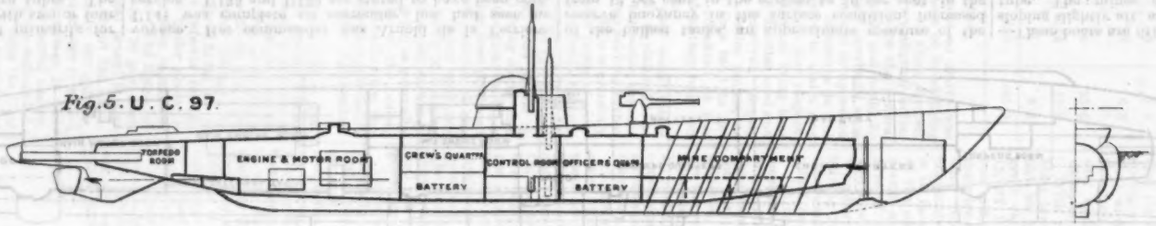


Fig. 6. U. 122. (U. E. LARGE MINELAYER)

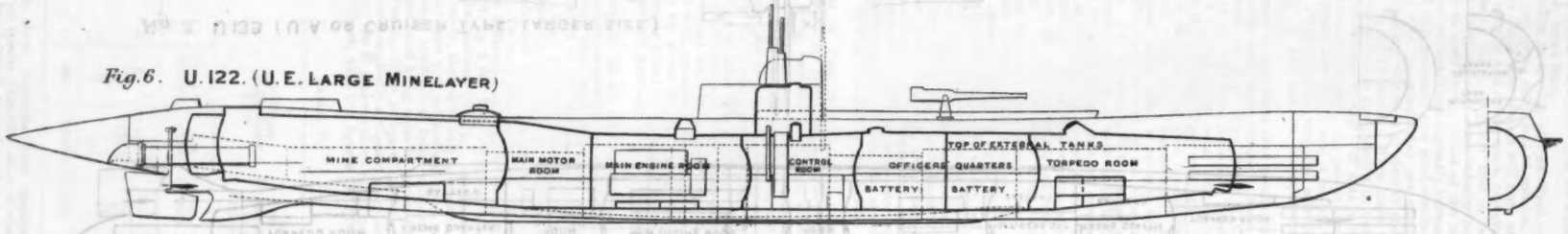
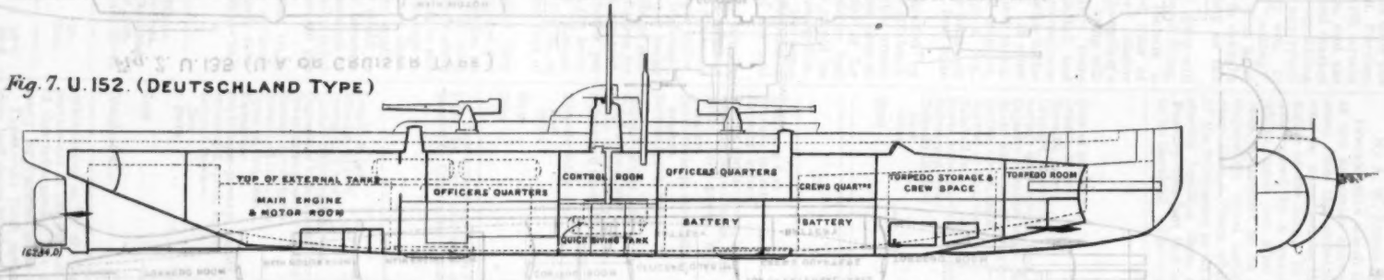


Fig. 7. U. 152. (DEUTSCHLAND TYPE)



through which the mines are discharged. The mines are stowed in racks in a large mine room at the after end of the boat, into which the fore ends of the tubes open. This type, especially the later class, was intended for mining operations at a distance, probably off the American coast. There are two classes of this type, but they differ a great deal in general design and qualities. The particulars are given on page 431.

U71–80 differ from all the ordinary U-boats in having internal main ballast tanks. They have a pressure hull of large diameter (16·4 ft. against 13·5 ft. in U161), and small external saddle tanks, which, instead of carrying water ballast, carry oil fuel. The two main ballast tanks are internal, the larger extending under the mine room and up the sides of the motor room, while the other is under the engine room and partly up the sides of that room. The two torpedo tubes are in the superstructure, the bow tube on the port side forward and the stern tube on the starboard side aft.

U117–126 are similar in general design to the UA type, except that the after torpedo room is extended forward to form a mine stowage space, thus pushing the engine and motor-rooms forward, and necessitating the auxiliary engine being omitted. This class was intended to carry 24 torpedoes, 12 in pressure-tight cylinders stowed along the side of the upper deck, and the remainder inside. The strong gun armament and the large number of torpedoes carried rendered them formidable craft. Four were completed in 1917 and five in 1918, but they do not appear to have done much service.

(f) UF or Flanders Coast-defence Type.—About 80 of this type were on order, but none were completed. No drawings or particulars are available, but it is understood they were generally similar to the medium UB class, but had a thicker pressure hull ($\frac{3}{4}$ in. or $\frac{7}{8}$ in., against $\frac{5}{8}$ in.) to enable them to better withstand the effect of depth charges. About 40 were in course of construction at the Armistice, but possibly the bottling up of the Flanders ports by Sir Roger Keyes rendered them useless for their intended purpose, and caused their construction to be delayed or stopped altogether.

(g) Converted Mercantile Submarines of the Deutschland Type (U152–157) (Fig. 7, above).—These have a length of 214 ft., breadth of 29½ ft., and draught of 15 ft. In the surface condition they displace 1,850 tons, and the capacity of the ballast tanks is 360 tons. The two engines are each 400 brake horse-power, and the motors the same. The surface speed is about 11½ knots. Two bow torpedo tubes are fitted forward and stowage arranged for 12 torpedoes. Two 5·9 in. guns are mounted and the original cargo space abaft the central compartment is used for the stowage of shell and ammunition. This type has no middle line or side ballast keels, as in all other types, but four short resting keels are fitted, two forward and two aft on the quarters. The necessary ballast (264 tons, or over 14 per cent. of the surface

displacement) is stowed in the tanks. The quick-diving and lubricating oil tanks are independent cylindrical tanks stowed between the two hulls, and not part of the ship's structure, as in other types. It was intended to install refrigerating plant for the cooling of the cargo and batteries, but this was either omitted or removed on conversion into a warship. It will be noticed from the profile view given in Fig. 7, page 430, that this type had an ordinary cargo ship sternpost and rudder, and that the bow is different in shape from that in other types, and is like that of ordinary merchant ships.

—	UC1–15.	UC16–79.	UC90–120.
Length, in feet	111¼	170	184
Breadth, in feet	10·3	17·1	18·2
Draught, in feet	10	12	12·35
Surface displacement, tons	177	417	480
Capacity of ballast tanks, tons	15	92	79
Brake horse-power of engines	90 (1)	300–600 (2)	600–650 (2)
Speed, knots	6·5	11–12	11–12
Normal oil fuel, tons	2½	46·6	63·6
Total oil fuel, tons	2½	63·2	76·0
Endurance	800 at 5½	10,000 at 7	8,000 at 8
Brake horse-power of motors	138 (1)	400 (2)	600 (2)
Submerged speed, knots	5	7	6½
Number of mines carried	12	18	14
Torpedo tubes	None	1 stern 2 bow	1 stern 2 amid-ships
Guns	1 mach.	1 machine 1 3·5-in.	1 machine 1 4·1-in.
Crew	16	28	32

Number of Submarines.—Admiral von Capelle informed the Reichstag Committee that 46 submarines were ordered before and 764 during the war, making a total of 810. Captain Persius states that 333, with a tonnage of 205,000, were authorised in September, 1918. If this is the case, progress on these could not have been great at the time of the Armistice.

Taking the highest-numbered boat of each type actually building at the yards just after the Armistice, a total of 568 completed and under construction is obtained. The details of this total are given in the next column. From other sources it appears that 212 U, 249 UB, and 80 UF boats were actually ordered from the shipyards, making, with 131 of UC type (there

—	U71–80.	U117–126.
Length, in feet	186½	267½
Breadth, in feet	19½	24
Draught, in feet	15½	13½
Surface displacement, tons	748	1,170
Capacity of ballast tanks, tons	84	345
Brake horse-power of engines	800–900 (2)	2,400 (2)
Surface speed, knots	10·6	14·75
Normal oil fuel, tons	76	92
Total oil fuel, tons	87	189
Endurance	7,800 at 7	15,000 at 7
Brake horse-power of motors	800 (2)	1,150 (2)
Submerged speed, knots	8	7·5
Number of mines carried	36	42
Torpedo tubes	1 forward 1 aft (in superstructure)	4 bow
Guns	1 machine 1 3·5-in.	1 machine 1 5·9-in. or 2 4·1-in.
Crew	32	45

were probably more), a total of 672 boats, instead of 810. As the hulls were generally built more quickly than the engines, batteries, motors, &c., could be supplied, it is probable that orders for the latter were placed with the makers in advance of the hulls from the shipyards, so as to be ready for the hull when required. This may explain the difference between 672 and 810. It will be noted that 385 boats were completed and that more than one-half of these were destroyed, the losses being spread fairly evenly over the three types. The 210 given as missing is eight more than the number stated to have been destroyed by the Allies during the war. It includes boats sunk by the Germans themselves. Taking 30 as the number completed before August, 1914, 355 were completed during 222 weeks of war; or slightly over one and a-half per week.

Yards Employed.—Two building yards—the Imperial Yard at Dantzic and the Germania Yard at Kiel—built submarines before the war. During the war at least 12 other yards were engaged on the work. Just after the Armistice 40 boats were under construction at the Vulcan Yard, 38 at Blohm and Voss, 29 at Germania, 28 at Weser, 25 at Dantzic, and 20 at Vegesack.

In this country three private yards and one dockyard built submarines before the war. The number was increased by Lord Fisher to 12 private yards and four dockyards.

The Germans appear to have arranged so far as was practicable for each yard to continue building the same type; 34 of the 40 building at the Vulcan Yard were UB type, 34 of the 38 at Blohm and Voss were of the UC type, the 20 at Vegesack were of the U type. To obtain quick production the shipyards built the hulls, the Admiralty ordering all the fittings and allocating them as the boats became ready. Pumps, blowers,

—	U Boats*	UB Type.	UC Type.	UF Type.	Total.
Completed—					
Surrendered	69	64	42	—	175
Missing	73	75	62	—	210
Building	53	62	27	41	183
Total	195	201	131	41	568

* Includes U, UA, UE and *Deutschland* types.

compasses and similar fittings were ordered from firms making a speciality of such fittings, and continuing to supply the same throughout. Captain Persius mentions six boats as having been sunk during trials, viz., U62, UB 79, 84, 106 and 114 and a UC boat. Four of these were amongst those surrendered. Two salvage vessels, the Vulcan and the Cyclops, the latter a new vessel, and two pressure testing cylinders, were available for salvage and testing purposes. The larger pressure testing dock was arranged to dock a submarine on either side of the pressure cylinder.

Cost of Boats.—The cost per ton increased very appreciably as the war progressed. The following figures are given by Captain Persius:—

In 1914	4,110 marks per ton
In 1915	4,450 ,,
In 1916	4,850 ,,
In 1917	6,070 ,,
In 1918	9,000 ,,

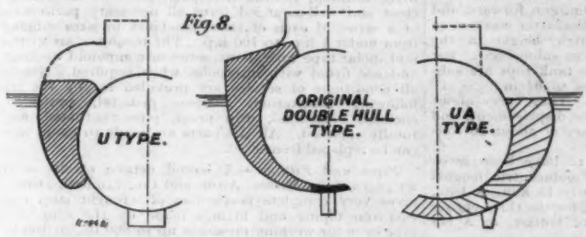


Fig. 8.

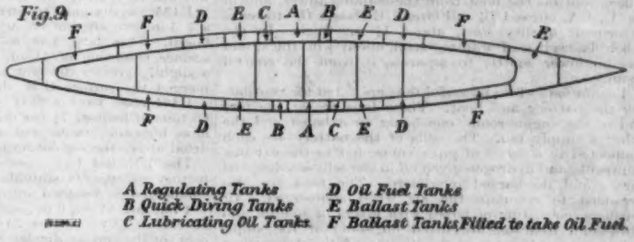


Fig. 9.

A Regulating Tanks *D Oil Fuel Tanks*
B Quick Diving Tanks *E Ballast Tanks*
C Lubricating Oil Tanks *F Ballast Tanks Fitted to take Oil Fuel.*

These figures are confirmed by those of Constructor Schürer for UB boats:—

	Marks.	Marks per ton.
Early UB boats cost	600,000	or 4,700
Middle UB boats cost	1,400,000	or 5,030
(1916) later UB boats cost	3,300,000	or 6,350
(1918) later UB boats cost	5 to 6,000,000	or 9,500 to 11,500

At the rate given by Captain Persius for 1918, a UA boat of the U142 class would cost about 20,000,000 marks, nominally 1,000,000*l.*, or nearly three times the cost of a K class submarine. An ordinary U boat of 800 tons would cost nominally 360,000*l.*, or about twice that of the same size of boat built in this country. The cost of the 385 completed boats is 1,390,000,000 marks to 1,400,000,000 marks, and the probable cost of the 810 of von Capelle would be not less than 4,000,000,000 marks, or nominally 200,000,000*l.*

Time of Building.—Captain Persius states that a boat of 800 tons at first took twenty-four months to complete, and this was increased later to thirty months and even more. According to German submarine officers, an ordinary U boat required seven to ten months and a UA boat eighteen to twenty months to complete. This appeared to be one of their objections to the UA type. Constructor Schürer states that the first UB boat (128 tons) was built in one hundred days, all 17 of the earlier class being delivered in seven months. Re-erection took a fortnight. The thirty boats of the UB 18–47 class (265 tons) were delivered in seven months. The latest class (521 tons) were under construction from twelve to eighteen months. Captain Persius' figures do not appear to be greatly in error when compared with these, it being understood that he includes time for trials, whereas Schürer does not.

In this country during the war it was generally believed that the time required for completion of German submarines was considerably less than those stated above. The times required for our own boats were compared with these false reports, and a certain amount of adverse criticism resulted. It now appears from the published German figures that our own time of construction was was not only as good, but even better than theirs. Six E class boats (700 tons) were completed by one firm in thirteen months, the first being delivered in eight months from the date of order. Other firms delivered similar boats in ten to twelve months. The first K boat (1,880 tons) was delivered in fifteen months, and six J boats (1,200 tons) by the dockyards in fifteen to eighteen months.

These times also compare very favourably with the performance of the Bethlehem Steel Company, U.S.A., who delivered 10 H boats (356 tons) in six to seven months, especially when it is remembered that in that case unlimited labour was available, whereas in this country it was limited and engaged in the building of other classes of warships, every one of which was most urgently required.

General Design.—All the boats, except the early UB and UC classes and U71–80, are of double-hull design, i.e., a strong pressure hull is enveloped wholly or almost wholly within a thin external hull, shaped primarily with a view to obtaining good surface speed. The external hull extends beyond and envelops the pressure hull at the bow and stern. In the UA and larger UE types it envelops the pressure hull transversely, but in the U, and, later, UB and UC classes, as also in U152–167, it extends transversely only to the turn of the bilge. As the UB and UC classes were evolved, the external hull extended downward towards this position.

The principal modifications from the original double-hull type of M. Laubeuf are shown in Fig. 8, below, the hatched portions indicating ballast tanks.

One modification in the U boat type is in the omission of the outer hull over the lower portion of the pressure hull, where it came very close and rendered erection difficult. The other is the position of the top of the ballast tanks, which is brought close to the surface waterline, the space between the hulls above the tank tops being free flooding and free venting. This arrangement reduces the reserve of buoyancy, but substantially decreases the time of diving.

Pressure Hull.—This is of circular section throughout, and is built in three main portions, a long truly-cylindrical portion amidships and two frustums of cones at the ends. The three parts are built independently. In the earlier boats the three portions were connected together by double-angle rings, the facing surfaces being machined, fitted with insertion, and bolted together. In later boats the connection was by butt-straps inside and out. The plating is flush, with double-riveted edge strips and butt-straps, the rivets countersunk head and point. In the majority of boats the edge strips are worked inside and outside, the former intercostal between the frames and the latter continuous. The complete double-hull boats (U117–126, U135, U139 and U142 class) have butt-straps inside and out, but the remainder have double-straps only on top and keel strakes. The thickness of plating varies from $\frac{7}{16}$ in. to $\frac{7}{8}$ in., and is of mild steel, but in U139 class it is 1¼ in. thick and of armour quality. In U142 class it is the same. The frames are generally angle bulbs, the standard spacing being 32 in.

External Hull.—This is ½ in. to ¾ in. thick, lapped at edges and strapped at the butts. The frames are angles worked at half the spacing of the pressure hull frames.

Subdivision.—Except in U139 and U152–167 classes, the subdivision of the main hull is wholly by transverse bulkheads. In the boats mentioned watertight decks are worked over the battery spaces, and in U152–157 also over the cargo hold.

In the U, UA and later UE classes the majority of the bulkheads are of the dished type, but in the smaller boats and in U152–157 they are straight. Usually the dishing is spherical and about 16 in., but in U139 it is cylindrical. The doors in the dished bulkheads are circular, about 36 in. diameter, and can be operated quickly and easily. They are arranged similarly to the breech block of a gun, i.e., with projections and spacings on two rings—one on the door and one on the bulkhead—of which one is fixed and the other rotated slightly when the door is closed. Being mounted on a screw thread, the movable ring draws the rubber home against its seating. When the door opens, the rotating ring is automatically locked, and thus the two rings are always in the correct relative position for closing.

Space Between Hulls.—In the original double hull design the whole of the space between the hulls was used for water ballast. In German submarines the space is not wholly used for this purpose. A typical arrangement of space is shown in Fig. 9. Two tanks aft and two forward are used for the stowage of oil fuel. Six ballast tanks, four aft and two forward, are fitted for oil fuel, and these are termed emergency oil fuel tanks. Two large tanks—termed regulating tanks—are fitted amidships, and are used for compensating for weights expended in stores, provisions, oil fuel, lubricating oil, torpedoes, or shell and ammunition. They are also used for variation of weight when the density of the sea water requires it. Their position amidships necessitates the symmetrical arrangement and consumption of the variable weights. Adjacent to the regulating tanks and symmetrically arranged about amidships are two tanks for lubricating oil and two quick-diving tanks. The latter are flooded when the boat begins to submerge, and are blown directly she is submerged. These are fitted in boats in which the tops of ballast tanks are well above the surface water-line, and lessen the time of diving. In a UC boat they diminish the time by five seconds. The trimming and torpedo tanks are fitted in most boats between the hulls. These, together with the regulating, quick-diving and lubricating oil tanks are not generally full, and must be made pressure-resisting.

Anti-rolling tanks are fitted in some UB boats, and also in U135 and U139 classes (see section of last class)

Their positions are at the tops of the ballast tanks, and they have holes at bottom and top. Their method of operation is not very clear, but it is presumed that the holes are made of such a size that flooding on the immersed and draining on the emerged side is slow and thus moderates the rolling.

Pumping, Flooding and Blowing.—The subdivision of the pressure hull not being good, a powerful two-stage centrifugal salvage pump is fitted in the control-room. It has a 9 in. suction main, with branches in all main compartments, and is capable of discharging 120 tons per hour against a 200 ft. head and 450 tons against 50 ft. head. Three smaller pumps—single-acting reciprocating—are fitted in the control-room, and also in the end compartments, all connected by main line pipe for dealing with smaller quantities of water in the ordinary operations of the boats. Flooding valves and vent valves to ballast tanks are large enough to enable the boat to submerge quickly.

Air at 160 atmospheres pressure is carried in reservoirs of 13½ cubic feet capacity, stowed in the superstructure or between the two hulls at the sides. The tank-blowing arrangements are elaborate, and provision is made to blow from :—(1) The central compartment, (2) the conning tower, (3) the forward compartment, (4) the after compartment, (5) a diver's connection through internal air pipes, (6) a diver's connection by pipes direct to tanks. With the conning tower hatches open, the tanks can be blown by air from a turbo-blower in the control-room. These turbo-blowers are direct driven by motors running at 4,000 to 5,000 revolutions per minute, and deliver 700 cubic feet to 14,000 cubic feet of air per minute at 1½ atmospheres pressure.

Periscopes and Conning Towers.—Most boats carry three periscopes, two main and an emergency. The main are used from the conning tower, and the emergency from the control-room if the conning tower is flooded, or the main are out of action. Large trunks fitted through the control-room for housing the periscopes cause the room to be very cramped. The commanding officer controls the boat from the conning tower, and in the U, UA, latest UB, and later UE classes the tower is of armour quality steel, about 1½ in. thick. In the other classes it is of ordinary steel, about ½ in. thick, and has no lower scuttle to separate it from the control room.

Ventilation.—Two powerful fans are fitted for ventilating the battery and boat. These fans are at the fore end of the engine-room, one being an exhaust and the other a supply fan. The cells of the battery are each connected to a series of pipes connected to the exhaust fan trunk, and hydrogen given off in the cells is exhausted direct and discharged overboard. The fans are also arranged to circulate the air when submerged. Air purifiers, consisting of boxes with layers of sodium and potassium hydrate, are fitted on some of the ship's exhaust branches to purify the air of the boat when circulating submerged. Oxygen is also carried and is freed into the air-circulating system to replace the oxygen used up by the crew.

Engines.—The majority of the boats are fitted with four-cycle six-cylinder engines. U135 and U139 classes have two main engines of 1,750 brake horse-power each at 390 revolutions per minute. U142 class were to have had engines of ten cylinders of the same size, each engine developing 3,000 brake horse-power. No boats of this class were completed, although the engines were ready. These engines have cylinders with a diameter of 530 mm. and a stroke of the same. The length of engine is 38 ft., including 5½ ft. for air compressors. The height is 11½ ft., and height above centre of shaft 8 ft. 11½ in. The breadth is 4 ft. 10½ in., and the engine completed is stated to weigh 76 tons, or about 56 lb. per horse-power. Auxiliary engines driving electric generators are fitted in the UA classes, and are used for charging the batteries, or as an electric drive by using the main motors. U135 has two auxiliary engines, each of 450 brake horse-power, and U139 has one of the same power. U142 class were to have been fitted with a 550 brake horse-power auxiliary engine. These auxiliary engines are in a separate engine-room to the main. The ordinary U boats and the larger UE class have engines of 1,200 brake horse-power, running at 450 revolutions per minute. It will be seen that the largest German submarine engine develops 300 brake horse-power per cylinder, and the ordinary U-boat engine 200 brake horse-power. The necessity for quick production of engines in this country during the war prevented progress beyond the standard 100 brake horse-power per cylinder. The smaller length of the larger-powered cylinder engine for the same total power has many obvious advantages from the point of view of hull design.

Speed.—Reports as to great speeds obtained by German submarines on trial reached this country in the first year of the war. These were apparently confirmed by our patrols, and caused some uneasiness. Information since received show that these reports were greatly exaggerated, but at the time they led to the ordering of the J class submarines by Lord Fisher. These were to have the greatest speed practicable with the existing type of engine, and were the first boats fitted with the 12-cylinder Vickers engine. The speeds, both surface and submerged, given in the tables for the various classes, are low, but are generally design figures, and would probably not be exceeded on trial. It has been pointed out by some authorities that the main purpose for which these boats were built, i.e., the sinking of merchant ships, did not require a high speed. This may be the case, but it remains the fact that the engine power of most of the types is high and the resulting speed less than might reasonably be expected.

U135 is of the same displacement as the J class submarines, and has the same main engine power, viz., 3,600 brake horse-power. The J class have triple screws, which is a slight disadvantage, but they obtained a speed of 19 knots to 19½ knots against 16 knots to 16½ knots in U135. The ordinary U-boat of U161 class, of about the same length and with the same engine power as our L-boats, has from 1 knot to 1½ knots less speed. The large middle-line ballast keel and the resting keels of the U, UB and UC types, the two side keels in the larger types, the fitting of guards to the hydroplanes, and other obstructions, must lead to increased resistance, but even when these are allowed for the speeds appear small. The submerged speeds are also low, although when the obstructions caused by the guns and open mountings, bulwarks around gun positions, obstructional wires, net cutters, and similar resistful fittings are considered, it is difficult to see how larger speeds could have been obtained without increasing the batteries and motors.

Stability.—The fitting of guns, and stowage of ready-for-use projectiles on deck, heavy conning towers, air bottles at top of boat, wireless masts and their heavy operating gear, must have made the problem of obtaining sufficient stability a most difficult one. It is not surprising, therefore, to find that some of the types required extensive modifications. The U117–126 and U139 classes were on completion found to be deficient in stability.

U139 class are stated to have had 3 in. B.G., and, on first visiting Germany, the Allied Naval Commission found that wood filling was being fitted in one of the class at the edges of the upper deck for a considerable length, to increase the buoyancy and stability. U141 on inspection was found to have this wood filling fitted.

U117–126 were designed to have a metacentric height in the surface condition of 17 in., and when submerged 7·6 in. It is not known what the actual figures were, but large buoyancy tanks, capacity 11 tons to 12 tons, are fitted right forward under the upper deck, and it has been stated that some of the mines in the top rows and one gun had to be omitted to obtain sufficient stability. A report of the German Submarine Acceptance Committee states that these boats had no available disposable weights to remedy the leakage of their oil-fuel tanks.

U135 was designed to carry a 5·9in. gun forward and a 3·5 in. gun aft, but on surrender the latter was not on board. This boat has a metacentric height in the surface condition of 11 in. and 5 in. submerged. For a slightly greater draught when the tank tops are submerged the surface G.M. diminishes to 6½ in.

U161 class have a B.G. of 5 in. They carry about 60 tons of ballast, 7½ per cent. of the displacement, and have buoyancy tanks with a capacity of about 20 tons fitted above the regulating tanks.

The UB and UC types appear to have been satisfactory as regards stability. The metacentric heights submerged as designed are respectively 13·8 in., 9·1 in., 7·1 in., and 14 in., 6 in., and 5·3 in. for the three classes of each. UC97 carries 24½ tons of ballast, or 5 per cent. of the surface displacement.

As already mentioned, the converted mercantile type carry 264 tons of ballast, or 14 per cent. of the surface displacement.

Ballast keels are fitted in all classes except U152–157. Resting keels are also fitted amidships in the U-boats to allow them to sit upright on the bottom. The ballast keels in U, UB, and UC types are very broad and built up of plates and angles, the ballast being in pigs stowed in the box so formed.

UA and later UE types have side ballast keels extending from 150 ft. to 200 ft. along the bottom.

Seagoing Qualities.—Some of the surrendered boats have been tried under service conditions. These trials have proved them to be good sea boats, keeping dry in a seaway and manœuvring well under helm. When submerged they do not prove quite so satisfactory, and some of the types take a great amount of time before their peculiarities are thoroughly understood. They dive quickly, but take up large angles of inclination longitudinally in the operation. They also appear sluggish in their movements when being kept on a straight horizontal course. The areas of the hydroplanes are smaller than those usually adopted in the submarines of other nations, and this may possibly account for their sluggishness. They also appear to have a certain angle of trim at which diving is carried out more easily than at others. The smaller areas of hydroplanes also render them less easily controlled at very slow speeds. They turn quickly when submerged, their rudder areas being greater than those usually adopted. So far as can be gathered from British officers who have been present on such trials, they prefer their own boats. There are, however, some details which they consider are better than in our boats.

Conclusion.—The foregoing outlines the main features of the vessels whose activities during the war must have caused the greatest anxiety to the Allied leaders and affected the daily life of all the subjects of the Allied nations, but particularly those of this country. The results are still being felt, and possibly more by the nation which built and used them than by others.

A few comparisons have been made with our own submarines. One further point, however, is worthy of notice. The largest completed submarines of both countries, i.e., U139 and K classes, are practically of the same displacement, viz., about 1,850 tons on the surface. The K class are 30 ft. longer than U139, and are fitted with steam turbines instead of internal combustion engines. The surface speeds are 24 knots and 16 knots respectively, the submerged speeds 8½ knots and 7·4 knots. K class have eight 18 in. torpedo tubes and U139 six 19·7 in. torpedo tubes. The guns for which the later K boats were designed were two 5·5 in. and one 3 in., compared with two 5·9 in. in U139. The normal oil-fuel capacities are 170 tons and 102 tons, and the total 330 tons and 390 tons. Endurance with the steam plant is less than with the internal combustion engines. Both classes have an auxiliary engine driving a dynamo. The other important difference is that U139 has an armoured pressure hull and the K class an ordinary pressure hull.

Further general comparisons between British and German submarines built during the war can be made by using the figures for British boats given by Sir Eustace d'Eyncourt in his paper read before this Institution last year and those given in the tables.

Such comparisons are useful and interesting so far as material is concerned. They cannot, however, include one all-important factor, and that is the personnel of the submarine services. In that respect we stand, I think, far and away above the Germans, and I am sure the members of this Institution will join me in the hope that this will always prove to be the case.

I have to thank the Director of Naval Construction for his permission to publish the information given in this paper.

CATALOGUES.

Machine Tools.—The Associated British Machine Tool Makers, Limited, 17, Grosvenor Gardens, London, S.W. 1, have sent us a copy of the first issue of a small monthly journal containing descriptions of their machines and articles on machine-shop practice.

Water Flow Measurement.—The Lea Recorder Company, Limited, 28, Deansgate, Manchester, has issued a booklet for civil engineers on the measurement of water flow by means of V-notches and weirs, and also dealing with the indicating and recording apparatus made by the firm. Useful tables and technical data are given, and the instruments are illustrated and described in detail as applied to the measurement of streams and rivers, compensation water, supplies to reservoirs, mine water, pump discharges, sewage flows, &c.

Motors and Dynamos.—A catalogue of direct-current motors and dynamos received from Messrs. H. T. Boothroyd, Limited, Bootle, Liverpool, gives in exceedingly clear and well-arranged form all necessary particulars of a series of each of these machines in sizes ranging from under 1 h.p. to 100 h.p. The machines are of the multipolar type with shunt, series or compound winding, and are fitted with interpoles when required. Nearly all conditions of service are provided for by the six following adaptations: Open pedestal, protected, enclosed ventilated, drip proof, pipe ventilated, and totally enclosed. All the parts are made to gauge and can be replaced from stock.

Pipes and Fittings.—A bound octavo catalogue of 96 pages, from Messrs. Aiton and Co., Limited, Derby, gives very complete particulars of wrought steel and cast-iron piping and fittings made by the firm. Oil pipe lines for working pressures up to 800 lb., hydraulic lines for 2,000 lb., and cast-iron pipes for 100 lb. are tabulated with all required dimensions for fitting up. Expansion bends and joints, steam separators, ejector heaters and a great variety of valves, coils and mixing vessels are shown. The catalogue also deals with light welded steel air piping, and with gangways, gratings, brackets, &c., used in connection with large pipe installations. Useful technical data and equivalent terms in English, French and Spanish are included.

Small Steam Engines.—An interesting and, in these days, remarkable catalogue of small steam engines comes from Messrs. Robey and Co., Limited, Lincoln. Single-cylinder, horizontal engines are made for powers as low as 2 h.p. economical and 3 h.p. maximum, with steam at 60 lb. pressure and in 15 larger sizes for working pressures of 60 lb., 80 lb. and 100 lb. The largest size gives a maximum horse-power of 64 and an economical horse-power of 52, at 100 lb. These sizes are repeated in engines of the vertical type, which are supplied with or without a vertical boiler. Six sizes of two-cylinder single expansion engines are also made with economical outputs ranging from 40 h.p. to 100 h.p., at 60 lb. pressure, and higher outputs at higher pressures up to 100 lb. A series of six engines of the two-cylinder diagonal frame type is also listed, the cylinders and guides being inclined at about 45 deg., with the crankshaft at the top. The diagonal engine takes up very little floor space, all the parts are easily accessible for cleaning, and the driving pulley is conveniently situated. These engines are largely used in textile mills and also by printers, dyers, bleachers and others. Finally, particulars are given of a series of horizontal compound engines, with the cylinders placed close together and the crankshaft working in two outside bearings. These engines are suitable for working pressures up to 120 lb., and are made in nine sizes, of which the smallest gives 11 h.p. economically and 15 h.p. as a maximum, while the largest size gives 96 h.p. economically and 128 h.p. as a maximum. The whole of the engines listed are made strictly to templates, so that the parts are renewable and interchangeable.

RATING OF MACHINERY.—A Bill is to be presented to Parliament to amend the law relating to the rating of hereditaments containing machinery. The word "hereditament" is to be deemed to include such machinery only as is fixed or attached to the hereditament. In the case of any hereditament occupied for any trade, business or manufacture, the expression "fixed or attached" shall be construed as applying to all machinery or plant in or on the hereditaments for producing or transmitting first motive power, or for heating or lighting such hereditament, but shall not apply to machinery which are only so fixed that they can be removed from their place without necessitating the removal of any part of the hereditament.